RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXI.

Published by order of His Excellency the Governor General of India in Council.

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY,
(AND BY ALL BOOKSELLERS).
LONDON: TRÜBNER & CO.

MDCCCLXXXVIII.

CALCUTTA:
PRINTED BY THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA,
1888

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1888. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1887.

Personnel of Survey and General Distribution.—On taking over the Directorship of the Survey in April last from Mr. Medlicott, I found the Staff of the Survey still below the normal number, owing to vacancies a long time unfilled; or under its effective strength through some of the officers being detached on special work.

The distribution over so vast an area as the Indian Empire, was as follows:—

Mr. Foote, on special deputation to the Mysore Government.
" Mallet, Museum and Laboratory.
" Hughes, special deputation with the Deccan Company, Hyderabad.
" Fedden, Vizagapatam.
" Hacket, Rajputana.
" Griesbach, just returned from Afghan Boundary Commission.
" Oldham, Salt Range.
" Bose, Chhattisgarh.
" La Touche, Assam.
" Middlemiss, Himalayas.
" Jones, Upper Burma.

Except from Mr. Hughes, who does not furnish us with any reports, satisfactory, and in some cases important, work has been carried out by all the officers named, though it has been of too detached a character to make any particular show in the progress map appended to this report.

Two of the vacancies have since been filled up in the appointment of Dr. Fritz Nöetling (Berlin University) as Palæontologist, and of Mr. Philip Lake (Cantab.) as Assistant Superintendent.

Mr. Mallet is again absent on sick certificate from 26th June for one year; Mr. Jones officiating for him as Curator and in charge of the Laboratory, though he is ready at the same time for any special and short field exploration. Mr. Hughes' deputation with the Deccan Company will not cease until 15th May 1888: and the

placing of Mr. C. L. Griesbach's services at the disposal of the Foreign Office for employment as Geologist to His Highness the Amir of Afghanistan for two years has just been sanctioned.

Perhaps for the first time, so large an indent has been made on us by Native States for deputation on special enquiries, a diversion from the proper work of the Survey which can hardly be avoided, although the officers can be ill-spared where so much having an economic value has yet to be worked out in the geological formations, the limits or relations of which are being systematically followed out. It is a distinction also, that the services of Mr. Foote and Mr. Hughes should have been specially asked for by the Mysore Durbar, and the Deccan Company respectively; while it is eminently satisfactory that their services have been, and are, appreciated. Mr. Foote has completed his deputation; but a still further call has been made on us by the Kashmir Government, and for this duty Mr. La Touche was selected.

The sudden death of Mr. Francis Fedden at Vizagapatam, on the 27th December last, has deprived us of one of our oldest colleagues, who had only just attained the long-waited-for promotion to the 1st grade.

The progress and occupation of the Survey has been in the following order:—

SOUTH INDIA.
Mr. Foote.
Mr. Fedden.
Mr. Lake.

Peninsular Region.—Mr. Foote has the Madras Presidency with its immense area of the crystalline rocks, or gneisses, among which, however, he is still carrying out his latest distinction of a newer (Dharwar) series. At present the great interest attaching to this series of transition rocks is not so much that it may fall in with, or represent, some or all of the various transitional formations of Central India, which have been treated of by so many of us under the names of Bijawars, Aravalis, Champanirs, and Chilpis: but that it is the series in which auriferous reefs are more particularly developed in the Madras Presidency.

Mysore and Bellary country: Dharwar series; auriferous.

I, myself, having had to work out the auriferous rocks of the Wainád region, which certainly appeared to me to occur among bands of the older gneisses, am unable to follow Mr. Foote throughout the whole of his generalizations, which would seem to tend towards an extension of the Dharwars into Wainád; but the fact still remains that he is perfectly clear as to the Mysore country to which his attention has been more thoroughly devoted. In this way he has become the best gold man we have; not an expert in the common acceptation of the term, which is properly a man capable of exploiting a region where gold is known to exist in greater or less quantity, but a geologist, experienced, *par excellence*, in the kind of rocks, or the particular formation likely to be auriferous in India.

The result of his deputation to the Mysore Government has been a lengthy report, founded on an extremely rapid tour over the very large area exhibiting gold indications in that State. I cannot but express regret that the time at Mr. Foote's disposal for examining such a large tract of country was all too small for the questions or the interests involved. His examination, such as it was, stands however, as the most reliable and scientific record of the auriferous veins of the country. To a very large class of men interested honestly in the occurrence of gold in Mysore, Mr. Foote's report is no doubt disappointing, because it fails to paint in glowing colours tracts of quartz reefs, or areas of gold washings which they believed, or had been persuaded to

believe were promising; or that it shows that the evidences he considers hopeful in other tracts were not thought worth other than passing examination by previous explorers. This is only in the nature of such an investigation, more especially since the deputation was to report on the auriferous tracts already visited by Messrs. Lavelle and Marsh in the previous year. Mr. Lavelle was the pioneer of the Kolar workings, and, what is far more to the point, a most successful pioneer. Mr. Foote's report was not suitable to these Records, but its material will be embodied in a paper shortly to be published.

Mr. Philip Lake, the junior Assistant Superintendent, has been placed under Mr. Foote's charge for the present; and it is pleasant to hear that there is much promise of the Survey having again gained by the judicious scheme of selection in the recruiting of our staff, introduced and most strictly watched by my predecessor Mr. Medlicott.

VIZAGAPATAM.

Mr. Fedden, who was transferred to the Madras Presidency at the end of 1886, took up work in the Vizagapatam District, an endeavour thus being made to fill in the large unsurveyed gap between the Godavery and the Ganjam Districts in the Northern Circars, and he had been going on steadily with his survey, but so far without finding anything of particular interest. His untimely death has practically stopped any chance of this district being further examined during the present season.

CENTRAL PROVINCES.
Self.
Mr. Bose.
Sub-Asst. Kishen Singh.
" *Hira Lall.*

My executive work closed with my boring experiences in the Chhattisgarh Coal-fields, the results of which are given in the concluding part of the last volume of the Records. These results show practically that throughout the whole area, as far as it is convenient to the trace of the Nagpur-Bengal Railway, there is only one tract near Korba which has shewn itself, by the borings, at all worthy of consideration as a likely place for workable coal of good quality. The credit of this find, which though it be among coal measures already known, is due to Sub-Assistant Hira Lal, who so far, and in this way, has done credit to the grand training he had under Mr. Hughes. A single boring, at the end of the season, when of course work could not be finished, has proved that this coal of Gordhewa does not change for the worse to the deep, as has unfortunately been the case with nearly all the other borings in other parts of the area.

CHHATTISGARH COAL-FIELDS.

I could not but marvel at this disparity between boring and outcrop samples, which certainly seemed to show that the boring samples might not be so free from admixture with shales as one is generally led to expect in work of this kind. Under these circumstances, and considering the interests involved, I have felt bound to recommend small trial pits as the readiest method—in the difficulty of getting improved boring plant or trustworthy workmen—for ascertaining the quality of the coal in bulk. Such pits are to be tried near Hingir, and at Korba; and further borings should be put down on Hira Lal's seam at Gordhewa to ascertain the area of that field.

TRANSITIONS AND VINDHYANS.
Mr. Bose.

In the early part of the season I devoted some time to the western edge of the great Chhattisgarh basin, where Mr. Bose had worked in previous seasons among the Vindhyans and Chilpis, though he had then failed to satisfy Mr. Medlicott or myself as to his

capabilities for distinguishing these two series in detail, or for the reporting on or mapping of them. However much he may have failed to satisfy us in this way, it is necessary to state that he did, after all, recognize an unconformity between the two; and under very exceptional conditions of stratigraphy. Mr. Bose was to have continued the work in this region; but even from here it has been necessary to move him, to more urgent, and as it turns out very interesting work, at the manganese ores near Gosalpur in the Jubbulpore district.

The Manganese ores of the Jubbulpore District.

I have just returned from an inspection of Mr. Bose's work as far as it has gone, he having brought features in the distribution and mode of occurrence of these ores to notice, which required testing in a more authoritative way than usual, owing to the ground having been previously visited by Messrs. Medlicott and Mallet. I was greatly pleased to find that Mr. Bose was not only doing his work well and carefully, but that he had made observations and recognized features which will lead to a more qualified view of the manganese ore capabilities, as well as towards a further elucidation of the origin of that form of decayed, or methylosed rock, so well known as laterite.

Work of Sub-Assistants.

Messrs. Kishen Singh and Hira Lal were engaged during the last season, the one about Mandla and Seoni in the Central Provinces, and the other among the coal-fields in Chhattisgarh; that is, each of these Sub-Assistants is following up the areas or boundaries of formations already ascertained by the executive officers of the Survey. It is necessary to mention this, because, unhappily, Babu Kishen Singh has got it into his head that he is now on independent work, and so fit for promotion. It may be as well to state at once that this is not the case; as yet, he is certainly not fit to be set on new and independent work. This is however quite a different matter to the doing of the work he has in hand, which I am only too glad to praise as well and carefully executed. At the same time I should wish, as soon as the time may come round, to recommend that he, as well as Mr. Hira Lal, should be better remunerated for their work: this has already been strongly advocated by my predecessor, and at the first opportunity I shall press it again.

Mr. Hira Lal has the luck to be working at the coal-bearing rocks, and I think I have sufficiently expressed my liking for him and his work in that connection in my last paper on the Chhattisgarh coal-fields.

Both Sub-Assistants have sent in their maps, accompanied by fairly interesting and readable progress reports.

CENTRAL INDIA.
Mr. Hacket.
Mr. R. D. Oldham.

Rajputana has been for many years Mr Hacket's area, and he is still in it, working out details of the very puzzling and complicated relations of the several series or groups of transition rocks. Up to the close of last season his work lay in the neighbourhood of Mount Abu; but we are hopeful that his investigations may extend more to the westward, where he may be able to touch on the more economically interesting Gondwanas, with their coal possibilities.

As stated in Mr. Medlicott's last annual report, Mr. Oldham was occupied in testing his own suggestion of a possible occurrence of coal measures with coal in Jessalmer, though he was not very sanguine of success. It was, indeed, more of a scientific generalization than a suggestion, and hopes were high that success might

attend it; but so far the promise is not good, as will be seen in the memorandum published in the present number of the Records.

Mr. Oldham.
Dr. H. Warth.

Extra Peninsular India.—Early last year, further evidence was sent in by Dr. H. Warth on the identity of the '*Olive Shales*' and '*Speckled Sandstones*' in the Salt Range geology. Mr. Oldham having been sent up in the previous season to settle the question, he was again despatched to the Salt Range to verify Dr. Warth's observations, which were published in the May part of last year's Records. The groups of rocks with boulder-beds at their bases, which have hitherto, in the eastern and western portions of the range, been considered, respectively, the one as of cretaceous, and the other as of upper palæozoic age, will now be merged in the name '*Speckled Sandstone*,' this group being, according to the latest utterance of Dr. Waagen, of the age of the upper coal-measures.

HIMALAYAS.
Mr. Oldham.
Mr. Middlemiss.

Having finished his work in the Salt Range, which also included a visit to the Dandot Coal Mining operations, Mr. Oldham then proceeded to Simla, preparatory to making an expedition to Ladak and back by Kashmir, according to the desire of my predecessor, with a view to determining how far the discrepancies between the sequence of beds in Kashmir, as described by Mr. Lydekker, and that of the Simla region were real. On return from other work early in November, he was deputed to look up the prospects of obtaining petroleum at Tijarah, near Ulwar. His report confirms our original examination, *viz.*, that the bituminous stuff obtained from Tijarah is merely an occurrence of combustible organic matter in a thin layer, or seam, associated with potsherds and other refuse formed on the site of an old cattle village.

Mr. Middlemiss has been steadily pursuing his proper work in the lower Himalaya about British Garhwal and Kumaun, the results of which he is giving in a series of papers in the Records. His work continues to be excellent, and there is no lack in his enthusiasm and energy.

KASHMIR.
Mr. LaTouche.

Sapphires.

The Kashmir Government having applied for a geologist to look up and report on the occurrence and possible exploitation of the sapphires in the Zanskar district, Mr. La Touche was detached from his recess work in Assam. He was only able to work for a month at the locality, which lies just below the snow line, mainly driving an adit, or cutting through the great mass of débris which had fallen down over the old diggings, though without reaching the sapphire rock, and thus the examination is yet incomplete. Waiting a better opportunity for re-exploration when the retreat of the snow will permit, his services have been very advantageously employed by the Durbar in examining the Jummu coal, originally discovered by Mr. Medlicott, on which he is inclined to look hopefully, provided some method can be devised, similar to that adopted in Italy, for compressing the unfortunately crushed and powdery fuel into bricks.

Jummu Coal.

UPPER BURMA.
Mr. Jones.

Mr. E. J. Jones was fully occupied until the end of the season in examining the principal coal-fields in Upper Burma, as well as the metalliferous mines in the Shan Hills, reports on which appeared in the last number of the Records.

Memoirs, Records, Palæontologia Indica, Manual.

Survey Publications.—Part I, of the twenty-fourth Volume of the Memoirs, *viz.* :—"Southern coal-fields of the Satpura Gondwana Basin," E. J. Jones, was issued early last year : it treats of what is more generally known as the Chindwara coal-field. Volume XX. of the Records contains twenty-three papers, besides other matter, four of the articles being of important economic value. In series X, Vol. IV, Part III, of the Palæontologia Indica, Mr. R. Lydekker has described the "Eocene Chelonia from the Salt Range." It was to have been expected that the concluding part of Dr. W. Waagen's great volume on the fossils of the Productus Limestone of the Salt Range would have been issued, but an unforeseen delay has occurred through the copies of the last three plates, which were despatched from Munich long ago, having been mislaid in the carrying agent's office. Part IV, "Mineralogy," of the Manual of the Geology of India, by F. R. Mallet, was issued in July last : it forms a very fitting completion of the Manual.

Library.—Two thousand and twenty-four volumes, or parts of volumes, were added during the year ; 1,270 by presentation or exchange, and 754 by purchase.

Museum.—Now that we have once more a Palæontologist on the Survey in the person of Dr. Fritz Nöetling, an endeavour is being made to bring the collections sent in from the field under thorough examination ; particularly the *invertebrata*, which have in great part lain by so long, owing to the pressing necessity during Dr. Feistmantel's time for treatment of the flora of the Gondwana Formation, the lower division of which, it is perhaps hardly necessary now to mention, includes the Indian coal measures. Up to this time, Dr. Nöetling has been engaged in working out the *ammonitidæ* collected by Mr. P. N. Bose in the Bág beds of the Narbada valley, which, I am informed, corroborate in every way the original conclusions of Professor P. Martin Duncan regarding the Cenomanian age of these beds. The Silurian and other fossils, to be referred to in Mr. Griesbach's forthcoming Himalayan Memoir, are also being examined.

The Geological and Mineralogical galleries are in perfect order, the collections being gradually added to by presentations or by exchange with American, Continental, and British Societies and Collectors, notices of which have appeared in each part of the last volume of the Records.

Tours of the Director.—Notwithstanding the inconveniences referred to from time to time in his Annual Reports by my predecessor, among which are the having to rely on the carrying on of the current duties of the office by any Geologist who may be at hand, instead of a special Assistant as is the case with other Departments, and the editing of the publications of the Survey; I have been able to make three short tours. These were to the crushed-coal outcrops near Teendaria in the Darjeeling District; to the Karharbari coal-field; and to the Manganese ore deposits near Jubbulpore, the need for an authoritative visit to which I have already indicated when referring to Mr. Bose's work there.

WM. KING,
Director of the Geological Survey of India.

CALCUTTA,
The 31st January 1888.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1887.

ADELAIDE.—Royal Society of South Australia.
BALTIMORE.—Johns Hopkins University.
BASEL.—Natural History Society.
,, Basel University.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
BOLOGNA.—Royal Academy of Sciences.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
,, Marine Survey of India.
,, Meteorological Department.
,, Natural History Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Queensland Branch, Royal Geographical Society of Australasia.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Academy of Sciences, Belgium.
,, Royal Geographical Society of Belgium.
,, Royal Malacological Society of Belgium.
,, Royal Museum of Natural History, Belgium.
BUDAPEST.—Hungarian Geological Society.
,, Hungarian National Museum.
,, Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Editor, Indian Engineer.
,, Editor, Indian Engineering.
,, Meteorological Department, Government of India.
,, Royal Botanic Garden.
,, Survey of India.
,, The Calcutta University.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CASSEL.—Verein fur Naturkunde.

CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
„ Forest Department.
DELFT.—Polytechnic School.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
„ Royal Dublin Society.
„ Royal Irish Academy.
EDINBURGH.—Geological Society.
„ Royal Scottish Society of Arts.
„ Scottish Geographical Society.
GLASGOW.—Geological Society.
„ Glasgow University.
„ Philosophical Society.
GÖTTINGEN.—Royal Society.
GRANVILLE.—Denison University.
HALLE.—Kais. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
„ Natural History Society.
HARRISBURG.—Second Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Okonomische Gesellschaft.
LAUSANNE.—Vandois Society of Natural Sciences.
LEIPZIG.—Geographical Society.
LIÉGE.—Geological Society of Belgium.
LILLE.—Société Géologique du Nord.
LISBON.—Geological Commission of Portugal.
LIVERPOOL.—Geological Society.
„ Literary and Philosophical Society.
LONDON.—British Museum.
„ Geological Society.
„ Iron and Steel Institute.
„ Linnean Society.
„ Royal Asiatic Society of Great Britain and Ireland.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
LYONS.—Museum of Natural History.
MADRAS.—Literary Society.
„ Meteorological Department, Government of Madras.

MADRID.—Geographical Society.
„ Royal Academy of Sciences.
MANCHESTER.—Geological Society.
MELBOURNE.—Department of Mines and Water-supply, Victoria.
„ Geological Society of Australasia.
„ Royal Society of Victoria.
MILAN.—Royal Institute of Science, Lombardy.
„ Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
„ Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NAPLES.—Academy of Science.
NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
„ The Editors of the "American Journal of Science."
NEW YORK.—Academy of Sciences.
PARIS.—Geographical Society.
„ Geological Society of France.
„ Institute of France.
„ Mining Department.
„ Société Académique Indo-Chinoise de France.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
„ Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SACRAMENTO.—California State Mining Bureau.
SALEM, MASS.—American Association for the Advancement of Science.
„ Essex Institute.
„ Peabody Academy.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TORONTO.—Canadian Institute.

TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Academy of Sciences.
" Imperial Geological Institute.
" Imperial Natural History Museum.
WASHINGTON.—Director of the Mint.
" Philosophical Society.
" National Academy of Sciences.
" Smithsonian Institution
" United States Geological Survey.
" United States War Department.
WELLINGTON.—Colonial Museum.
" Department of Mines, New Zealand.
" New Zealand Institute.
" Surveyor General, New Zealand.
YOKOHAMA.—Asiatic Society of Japan.
" German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Natural History Society.
The Secretary of State for India.
The Governments of Bengal, Bombay, India, Madras, North-Western Provinces and Oudh, and the Punjab.
Chief Commissioners of Assam, Burma, and Central Provinces.
The Commissioner of Northern India Salt Revenue.
The Resident at Hyderabad.
The Surgeon-General, India.
The Quarter-Master-General of India, Intelligence Branch, Simla.
Foreign, Home, Public Works, and Revenue and Agricultural Departments.

Number of volumes and parts presented during 1887	. . .	1,270
Ditto purchased do.	. . .	754
	Total .	2,024

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal, *and* Kumaon, Section III, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*—(With 3 plates.)

PART I.

BASIC LAVAS NORTH OF DUDATOLI.

In due order I must now sketch in brief outline some basic lavas and associated rocks which lie to the north of the Dudatoli area, and which occupy a large portion of the Syoons of Dhanpur, Ranigadh, Tili-Chandpur, Chandpur, and Nagpur Tala. As in the case of the acid lavas of Lobah, but little petrological work can be done in the field without the aid of the microscope to determine, in the first instance, what is the intimate structure of these, to the eye, absolutely compact and enigmatical rocks. It will therefore be necessary to follow the plan adopted in my last paper of very briefly describing the extension, lie, and general habit of the rocks as a whole, giving the results of the examination of numerous microscope slides in more detail. The whole of these notes will then form a body of data which will be a useful preliminary to the final description of the fully mapped area.

Like the ancient rhyolites of Lobah, these basic rocks belong to a geological system distinctly newer than the schists among which the gneissose-granite of Dudatoli is insinuated. The fault which separates the older and the newer series near Lobah, in its curve round the north portion of the Dudatoli area, similarly divides the rocks about to be described from the older Dudatoli schists. The discordancy in the dips, and in the nature of the rocks on each side of the faulted boundary, give it a great structural importance, and make it a striking feature both in the field and on the map. Its great extension, running as it does for 30 miles at least, proclaims it at once as a master-fault that has had no little influence in determining the present geology of this part of Garhwal. On its south side it leaves exposed the elongated quaquaversal synclinal of the Dudatoli schists, a long flat synclinal of great regularity—an oasis as I have previously termed it—among much more disturbed and highly tilted rocks, on to which we step when the faulted boundary is crossed. These newer lavas and other stratified deposits dip *away* from the Dudatoli centre in quite as marked a manner as the older schists dip *towards* that centre; and being only at present known on the north, north-east, and east sides of the older schistose area, they therefore form the north-east half of a quaquaversal anticlinal elongated in a direction north-west and south-east, and which, if completed, would cover in the whole of the present Dudatoli area, that is to say the ground represented on the map facing page 142, Vol. XX of this publication.

I must again refer the reader to that map, not for the purpose of giving at present a detailed description of the stratigraphy, but in order to roughly indicate the general positions of the rocks now to be discussed, and to give a connection, however superficial, between these notes and Sections I and II of this series. A few miles to the north beyond the limits of the map, but contained in sheet 14 of the 1 inch scale, from which the map is taken, the higher parts of the Dobri-Pandubri ridge are occupied by a massive limestone, an undoubted portion of the same rock as was des-

cribed in the Lobah area.[1] Only a small crescent of outcrop with the concave side towards the south has escaped the fault, but there is sufficient to shew that it overlies a purple and grey slate series with a suspicion of volcanic breccia among it closely resembling the purple slate and volcanic breccia series found in west Garhwal nearer the plains.[2] The horns of the crescent abut against the great fault, and outward from these points we travel over an ascending series of the volcanic rocks consisting chiefly of basic lavas and associated quartzites. Above the west-north-west horn, however, there is about a square mile of outcrop of the acid lava alluded to in my last paper and described microscopically by reference to a specimen, No. $\frac{7}{789}$, from the head of the stream running by Peera. Above it come the more basic lavas by gradual interbedding with, at first, a very large thickness of sedimentary rocks, *viz.*, purple and white quartzites and conglomeratic quartzites. Although the sequence here shews unmistakably the connection subsisting between the two volcanic series, and between those series and the massive limestone, yet it is complicated to a small extent by an inversion of the whole, so that the apparent dip in this one corner of the district is towards the south-south-east instead of in the opposite direction. This inversion is rapidly resolved within a radius of a few miles; as a traverse along the ridge towards Charmarguri trigonometrical station makes very evident: the purple quartzites and coarse grits rise more and more to the vertical and then fall again, but with an exceedingly high dip towards the north-north-west. They eventually settle down to a dip of about 70° in that direction. The limestone at Dobri and Pandubri trigonometrical stations is devoid of this complication: the angles are steep, sometimes even approaching 80°, but the dip, both of the limestone and of the superposed basic lavas and quartzites, is steadily towards the north. The intervening rhyolites are absent round the crescent of limestone in this neighbourhood, and they do not again make their appearance until Lobah itself is reached.

With dips radiating between the north-west and north-east, usually steep, but more so near the Ganges towards the north-west than along the Pindar river and round about Chandpur Garhi, these beds continue over the large area enumerated in the beginning of this note. The dip is, however, in many isolated cases in an opposite direction, and the same beds often seem to be repeated, either by faulting or by sharp flexure; so that there may not be such an immense thickness of them as would at first appear. Matters are also rendered difficult by a reappearance of the massive limestone near Limeri on the Pindar river. But as the stratigraphical details of much in this neighbourhood are at the present moment not worked out, further remarks on this head would be premature.

North of Sirobagar.—Several of the specimens next to be described agree in a way that can scarcely be accidental with those described by Col. McMahon from the Darang ridge,[3] and also with some from the lower Chakrata volcanic beds in Jaunsar, *viz.*, Nos. $\frac{6}{406}$, $\frac{6}{407}$, and $\frac{6}{408}$ from the Gam Gadh, collected by Mr. Oldham. The likeness is not altogether a superficial one, as will be seen from the sequel, so that, though I am generally averse to generalizing on petrological grounds, I cannot refrain from drawing the reader's attention to the probable contemporaneity of these three sets of lavas. It should be borne in mind, parenthetically, that the lower

[1] See Rec. XX, p. 162. [2] See Rec. XX, p. 34. [3] See Vol. XV, p. 155.

Chakratas are the oldest beds in Jaunsar, and that beds underlying the volcanic series in the district I am describing have at their base some splintery slates, grey and purple in colour and without a trace of schistosity, abutting against the Dudatoli schistose series. The regional metamorphism of the Dudatoli schists must therefore be attributed to a cause which acted before the younger slates, limestones and superposed lavas were laid down. Thus those schists belong to a very ancient land area; and even the subsequent intrusion or development of the gneissose-granite in them must date back to a geologically remote period, since the attendant garnets in the schists as previously shewn (Section II) were also anterior to the deposition of the upper portions of the younger series near Lobah, and contemporary with that of the ancient rhyolites.

The following specimens are from the cuttings in the road which runs from Srinagar to Rudarpraeg along the river. Taken together they form an important series illustrative of a structure constantly present in nearly every crystalline igneous rock that I have yet seen in this section of the Himalaya. I refer to the apparent foliation of the rock at its upper and lower surfaces. At one end of the series we have a massive compact rock, breaking independently in any direction after the manner of an ordinary trap. It is purple, or greenish purple in colour, and crowded in many parts with amygdules of red and white chalcedony, of dark green chlorite, of calcite, and occasionally of more than one of these substances together in the same amygdule. At the other end of the series we have a rock undistinguishable from a chloritic schist, of a pale greenish grey colour, slightly soapy to the touch and very fissile. It is almost as fissile as a slate, the dip of the laminæ being parallel with the dip of the beds. But the chief point of interest in the rock seen macroscopically is that there are several dark-green flakes covering the cleaved surfaces, and some few of chalcedony, which are nothing less than drawn out and pressure-flattened amygdules. Between the two extreme forms there are a number of intermediate ones shewing more plainly, and step by step, the transitions from the perfectly formed amygdules to the mere blotched remnants of them, flattened, drawn out lengthwise, and sometimes separated into shreds. Along with this change in the amygdules the rock itself becomes more fissile, and develops gradually a greener colour through the dissemination of the chloritic amygdaloidal contents (see diagrams I, 1, 2, and 3).

Taking into consideration the perfection of the transitional varieties in this series of specimens, it seems impossible to explain them except on the supposition of pressure and cleavage acting after the rock had assumed its solid form. For, it is to be noticed, the amygdules are composed of just those minerals into which a trap rock naturally changes through the alteration of its primitive mineral components, and the formation of secondary products. Chlorite, calcite and chalcedony are always due to secondary causes when present in igneous rocks—secondary causes which are not likely to have come about rapidly, and whilst the rock was still warm from its eruptive phase, but which are universally regarded as working slowly, *e.g.*, steady pressure in the presence of water or steam, but continued over a long period of time. Thus we seem bound to admit a primarily molten condition of the rock, full of vesicles which cooled and hardened; after this a gradual absorption of some of the mineral constituents and the re-depositing them in vesicles as chlorite, chalcedony, &c.; and

after this a pressure acting on the cold and solid rock which re-arranged the particles of the rock at right angles to itself, *in toto* producing cleavage and a spurious schistosity.

It should be noted here that the more fissile varieties are always next the outer surface of the bed, or set of beds, whilst the massive non-fissile rock is always near the centre, just as in the case of the gneissose-granite bands. The pressure foliation which I here advocate as the explanation in these basic rocks, I have, in a preceding paper, indicated as the possible explanation of much of the foliated and semi-foliated forms of the gneissose-granite; and further on I shall shew that a microscopical investigation of the Hansuri band bears out this view.

Specimen No. $\frac{7}{778}$, locality a little north of Sirobagar. Sp. gr., 2·75. Contains 56·91 per cent. of silica. This was the most massive, and the least altered by subsequent pressure.

Microscopical.—A very large portion of the ground-mass appears dark and unchanged under crossed nicols, indicating the presence of a glassy base or one very slightly altered indeed. The whole of the slice appears even darker in tint than the glass of the slide owing to the presence of a large amount of opacite in irregular minute grains. Thickly disseminated in the base is a sprinkling of microlites of plagioclase felspar, all radiating in different directions. They generally shew twinning, the twins extinguishing under crossed nicols very nearly parallel with the nicols and almost simultaneously; a very few larger micro-crystals of plagioclase dotted about the field shew it more markedly. This is characteristic of oligoclase. A faintly fibrous green mineral, probably chlorite, is irregularly intermingled with them, and has no effect on polarized light. It is also collected together in many of the amygdules, which are usually round or oval in section. In some pear-shaped amygdules containing this green mineral there is evidence of a slight general effect of greater darkening in certain directions when the nicols are crossed and the stage revolved, but generally they remain completely dark. There is no trace of micro-quartz in the slide, the only form of silica being the chalcedony of the amygdules. This appears rather to have been injected from a foreign source into the rock than to have been derived from the surrounding portions of it. There are no minerals belonging to the amphibole or pyroxene groups. The amygdules of chlorite may, it is true, represent material derived by alteration of one of these minerals; but from the large amount of viridite in the ground-mass, they may be merely segregations of that material which in itself never had the opportunity of crystallizing out in the form of hornblende or augite; in other words, as Col. McMahon suggests for the Darang lavas, the glassy base may have been partly altered into viridite. The most marked appearance in this rock-slide is undoubtedly the chalcedony. The amygdules of it are frequently encased in a thin layer of chlorite and calcite. A concentric zonal arrangement of the silica marks the growth lines within the original vesicle. Irregular cracks traverse the substance. On crossing the nicols the mass of the amygdule splits up into sub-angular portions, each of which shews a radiating or sometimes parallel streakiness of grey-blue and pale yellow colours, which darken in directions parallel with the crossed nicols when the stage is revolved, thus partially displaying a black cross. The zonal arrangement seen by ordinary light is always at right angles to the radiating structure seen in polarized light.

No. $\frac{7}{776}$. A dark greenish-grey compact rock, slightly fissile, the amygdules a

little flattened and drawn out. This specimen very much resembles $\frac{7}{176}$ being taken in fact from almost the same locality. The ground-mass is very slightly coarser and richer in microlites of oligoclase. The latter are longer and very slender, almost like hairs, and often collected in stellate or cruciform groups. The large amygdules shew no differences worthy of note except with regard to their included crystallites. These are larger and appear to be mulberry groupings arranged in rod-like forms as well as circular. The chlorite amygdules are very marked, each with a border of chalcedony. Another set of irregular lacunæ are filled by an intimate granular mixture of viridite and chalcedony. There is then no radiating but only a very fine granular structure under crossed nicols, the viridite having hindered the proper action of the spherulite-forming forces.

No. $\frac{7}{178}$. A greenish grey very fissile rock, the amygdules being completely drawn out into blotches. It is taken from near the same locality as the two previous specimens, but not far from the surface of the flow. It resembles them very much in its intimate structure, but the re-arrangement of the particles of the rock in parallel directions is as marked under the microscope as is the fissile character in the hand. The microlites of triclinic felspar are a little more ragged and kaolinised, and are not so sharp as in the preceding examples; still there is no clastic appearance whatever, no suggestion that it is an ash. The lacunæ full of chlorite appear teased out at their ends and amalgamated more or less with the ground-mass as also do the clusters of opacite. The slice has a general striped appearance in consequence. The teasing out of the opacite clusters is very characteristic, and perfectly resembles the spluttering caused by a bad pen.

No. $\frac{7}{179}$. A slightly coarser grained rock than the above, of greenish-grey colour, from the same locality. The amygdules to the eye have almost lost their individuality. The parallelism of some of the larger needles of triclinic felspar and of the opacite, and the thin drawn out shred-like edges of the green mineral where it fills lacunæ, all shew the foliated or cleaved condition of the rock perfectly well. Much of the green mineral in the ground-mass appears restricted in a more marked way than in any of the other specimens, as though, owing to the coarser nature of the rock, it represented the altered result of some previously half-crystallized mineral. Under the $\frac{1}{4}$ inch objective there can be seen numerous small fragments and aggregates of a greenish-yellow mineral. It is impossible to say whether these belong to epidote, which seems most likely, or to some form of amphibole or pyroxene.

Gwar and Biraon, along the ridge N. from Charmarguri trigonometrical station. —The first three specimens to be mentioned have a very general resemblance to those from N. of Sirobagar, but the remainder shew a gradual change into a completely holo-crystalline rock. The localities are within a few miles of one another.

No. $\frac{7}{180}$ *Biraon.*—It very much resembles No. $\frac{7}{176}$ from near Sirobagar. A good many of the lacunæ filled with chlorite are teased out in appearance and the arrangement of the microlites of felspar is somewhat parallel.

No. $\frac{7}{181}$ *Biraon.*—Under the microscope this rock presents a wavy, drawn-out aspect (not unlike flow-structure) of alternating layers of viridite and finely granular quartz, containing great numbers of twisted and broken microlites of oligoclase. The pale bright green layers of viridite under the $\frac{1}{4}$ inch objective have the usual fibrous, faintly linear arrangement, which so strangely mimics flow-structure in a glassy rock

that it is difficult to explain them entirely on the supposition that they are only drawn-out amygdules, and not part of the original glassy base altered into viridite. Probably the truth lies between the two. The granular quartz layers, however, are undoubtedly merely a further stage of a crushing out of the chalcedony amygdules, or rather of the less pure ones mentioned in No. $\frac{7}{776}$. Magnetite is present in large quantities, as clusters drawn out with the rest of the rock structure, and twisted into most fantastic shapes. Under the high powers it appears to be aggregations of very small four-sided figures. There is another mineral which cannot well be distinguished from the magnetite under the 1-inch objective, but which, under the $\frac{1}{4}$ and $\frac{1}{8}$ inch, comes out distinct from it. It is present in the form of irregularly circular or hexagonal figures, of dull olive-green colour and with no action on polarized light. With them are associated some very minute red garnets, so that it seems probable that the former are the melanite variety of garnet. Epidote in brightly polarizing grains and in short prisms is also present in very small quantities.

No. $\frac{7}{783}$ *Gwar.*—This specimen and the next to be described both shew a smaller amount of the original glassy base and a relatively more developed stage of the microlites of felspar. The present specimen is an aggregate of small micro-crystals of oligoclase in lath-shaped sections very well and strongly developed, but shewing a considerable amount of granular kaolinisation under polarized light, with feeble colours. They are set in a very small amount of base in which the opacite is scarcely separable. Lacunæ of chlorite, though of irregular contours, are very distinct from the base itself in which there is but little of the green mineral. There is no free quartz, nor are there any amygdules of chalcedony.

No. $\frac{7}{784}$. *Gwar.*—This rock is a fortunate link between the more eruptive character of the foregoing specimens and the more thoroughly crystalline forms to be described next. It is not composed entirely, either of large crystalline elements, or of microlites; but it is a porphyritic rock. The porphyritic crystals are large, frequently rectangular felspars, much altered into quartz of corrosion, but there are not many in the slide. There are also a few crystals intermediate between these and microlites, which often shew twinning, the angle of the hemitrope section giving between the two extinctions a value of about 38° in some cases, and lesser values in others. The porphyritic crystals, owing to their corrosion, are quite unrecognizable; the developed quartz granules not even polarizing concordantly. The microlites in the glassy base, which form the ground-mass, all shew extinction angles of the smallest possible amount, *viz.*, about 3°. Many are twinned, the twins extinguishing almost simultaneously. It seems probable therefore that the whole of these felspars are really triclinic and oligoclase. The rest of the ground-mass closely resembles that of Nos. $\frac{7}{778}$ to $\frac{7}{779}$.

No. $\frac{7}{785}$ *N. of Gwar.*—A finely holo-crystalline greenish rock. Sp. gr. 2·70. In the hand, and when a thin slice is held up to the light, it appears to be a mixture of felspar and some greenish mineral; but when it is applied to the microscope the felspar is discovered to contain quartz-pegmatoid and also quartz of corrosion (Fouqué and Levy); that is to say, the felspar has intergrown with the quartz to form the pegmatoid structure, and has been changed by infiltration of silica to form the corrosion structure. Very little of the original felspar is left in the latter case, but sufficient to be recognized.

In diagram I, 4 I have sketched an example of corrosion of the felspar, which very much resembles that figured by Fouqué and Levy,[1] but in the slide under description there seems to be an intermingling of this structure with the pegmatoid structure. The cuniform outlines of the quartzes in the felspar shape, which are sometimes Z-like, sometimes hexagonal or irregular, are fitted together at their angles and occasionally run into a vermicular radiating structure towards some point in the changed felspar. They always extinguish light under crossed nicols simultaneously in the same crystal of corroded felspar, that is to say, each of the semi-detached portions of the quartz have a connected crystalline structure as if they were figures stamped out of a single quartz. According to Fouqué and Levy the development of the quartz of corrosion must have taken place after the solidification of the felspar, and there seems no doubt that this has been the case here, for the original outline of the felspar is quite sharp and distinct as indicated by the edges of the corrosion quartz. Nevertheless triangular quartz sections joined to each other, apex to base (not seen in the diagram) in lines parallel or radiating towards a centre,— all of which structure is characteristic of quartz-pegmatoid—indicate simultaneous crystallization of felspar and of quartz. Since then these two structures are found together in the same rock melting into each other, though one may be a primary and the other a secondary structure, they must be nearly related. Possibly the latter followed very hard on the crystallization of the felspar; or the originally felspathic rock was sufficiently re-heated and charged with silica as to allow the molecules to re-arrange themselves into the pattern of quartz-pegmatoid.

A previously twinned structure in the felspar is indicated by the quartz of corrosion pattern polarizing in different shades on each side of the median line. The singly twinned felspars and the non-twinned felspars may be orthoclase, but it is difficult to say with certainty.

The remainder of the rock consists mainly of long, singly twinned prisms of dark greenish-grey colour under the 1-inch objective, but which under the higher powers shew as crystal outlines with minute grains of chlorite dotted about them. The few spaces of the field between and among the above mentioned minerals are occupied by chlorite, whose minute portions and fibrils polarize independently, giving a speckled or irridescent effect. Opacite abounds, in irregular grains.

This altered rock may have been originally a diorite or syenite; but it is impossible to say with certainty whether the felspar was orthoclose or not, and whether the greenish-grey prisms were originally hornblende or augite. On the whole, analogy would prefer to call it a metamorphosed diorite.

No. $\frac{7}{186}$. *N. of Gwar.*—A reddish finely holo-crystalline rock. Seen in the hand alone it resembles a diorite or syenite; but under the microscope, as in the previous example, the felspar appears changed into quartz of corrosion. There is also apparently some original granular quartz, not merely replacing the altered felspar. Quartz-pegmatoid structure is rare. The green mineral is altered beyond recognition into chlorite, but from the long prisms and by analogy it seems likely to have been hornblende. They are often long, singly twinned, dark grey, prisms, intact,

[1] Minéralogie micrographique. Planche XI, 2.

but having very little effect on polarized light. Opacite is present in grains and also in irregular blotches and pseudomorphs after replaced crystals of the unknown green mineral.

No. $\frac{7}{786}$. *Across the river opposite Limeri near Rudarpræg.*—A dark-green, coarsely granular rock with glistening crystals. Sp. gr. 3·06. It is perfectly holocrystalline, containing large lath-shaped prisms of felspar which remain uniform under polarized light, or darken so slightly, owing to their alteration, as to be undeterminable, by the extinction angles. There is a yellowish or greenish mineral polarizing in bright colours. Most of it, of a pale and cold tint is not dichroic and is much cut up by cleavage planes, which blacken and become wider in certain portions of the crystals. A broken octagonal section shewed three very distinct cleavages (see diagram I, 5), the most developed being parallel with the clino-pinacoid, and two others, nearly at right angles to each other, being parallel with the faces of the rhombic prism. The mineral is therefore diallage. Other sections of it shew it to be diallage or augite according as the clino-pinacoidal cleavage is strongly or weakly marked. The outer portions of some sections of this mineral shew a change from the cold yellow, which is not dichroic, into a warmer more greenish-yellow, which is highly dichroic. They also shew in parts the cleavage of hornblende. A hexagonal basal section, (see diagram I, 6), adjoining one of these hornblende borders shews the characteristic rhombic cleavage of that mineral, the angle measuring 123.° This section is strongly dichroic and extinction takes place under crossed nicols dividing the angle of 123.° The rock contains therefore both hornblende, and diallage or augite; and the first seems to be produced by alteration of the others. A further stage of alteration is reached by the production of chlorite, which in many cases replaces the whole of the green mineral and is invaded by blotched parallel lines of magnetite, which has been aggregated by infiltration along cleavage cracks. The chlorite is in fairly large, fan-shaped tassels, which polarize light in pale but brilliant colours. The felspars are the most perfect in shape and crystallized first. Then came the green mineral, which only very occasionally has a half-perfect crystalline form. Finally, there is a small amount of quartz, filling in the inter-spaces. It is never present in rounded grains or regular hexagons, but always in groupings suggestive of a secondary origin by corrosion. The irregularly shaped grains are roughly fitted together, but with thick dark bordering lines, and not in polysynthetic aggregation. They polarize simultaneously in groups, and in many respects resemble the corrosion quartz in Nos. $\frac{7}{786}$ and $\frac{7}{785}$, but they never so manifestly take the place of the felspars as in those rocks.

There are other small groups of a clear colourless mineral with a tesselated appearance which remain dark under crossed nicols. They must be tridymite. (See diagram I, 7.) Along with much of the chlorite and the secondary corrosion quartz just mentioned they fill up lacunæ among the other crystalline elements of the rock and are probably due to secondary causes entirely.

This is an interesting specimen in connection with those previously described, for it is the first having a holo-crystalline structure, which definitely shews what the original green mineral was which is represented in the more eruptive rocks by chlorite or some unrecognizable mineral. I will return to this subject after some few more rocks from a neighbouring locality have been described.

No. $\frac{7}{461}$ *Sonal near Dhanpur.*—A greenish-grey finely granular rock. It is holo-crystalline, composed of triclinic felspars in long blades, and augite in broken prisms and a few basal sections. The augite is of pale greenish-yellow colour. It is not dichroic, and the octagonal basal sections shew cleavage angles of about 84°. The prisms also shew angles of extinction at their sides in some cases nearer 30° than 20°. Thus there is no doubt that the mineral in this case is augite, and not hornblende. Only in a few places in the slide has the augite become altered at the edges into a much warmer, darker, dichroic mineral. This is no doubt a stage preceding the development of hornblende. There is no chlorite in the rock at all. The polarization colours of the augite are very brilliant. The triclinic felspars are much kaolinized and shew but little twinning and darkening under crossed nicols. Its species cannot therefore be determined. There are a few irregular granular quartzes in the rock, but there is no corrosion-quartz certainly present. Opacite is present in irregular grains and pseudomorphous after augite. The mineral composition of this rock taken in connection with that of the preceding one indicates that among the whole spread of these basic lavas there are numerous passages between gabbros, diabases, and diorites; and it follows that the hemi-crystalline representatives of these which only contain the green mineral chlorite cannot therefore be called definitely either basalts or andesites.

No. $\frac{7}{413}$. *S. of Dhanpur.*—A greenish grey fissile rock. Under the microscope it is composed of irregular layers of chlorite and granular quartz set in a still finer matrix of broken and crushed up material, cataclastic in nature perhaps rather than pyroclastic.[1] It seems to be a further stage of the crushing up of a flow, in which the triclinic felspar has become kaolinized, and corroded, and rolled out, as it were, under pressure into granular quartz interbanded with chlorite. Opacite is in irregular grains and in long dusty clouds. The rock is therefore a chloritic schist which represents the ultimate stage of alteration of the basic lava.

No. $\frac{7}{418}$. *Near Bhatkúwáli.*—An inky-purple coloured, finely cleaved rock. This is so often found associated near the edges of the undoubted lava flows that, though it has all the appearance in the hand of being a slaty rock, it must, I think, be put down as a crushed igneous rock, the same generally as the last described. Under the microscope it is seen to be composed of a very fine clear granular matrix, very densely crowded with opacite in hazy clusters drawn out with the cleavage of the rock. When the nicols are crossed the ground-mass shews a very fine crypto-crystalline assemblage of little needles of felspar and other granular material of the finest description. There is no augite or other green mineral. I cannot say definitely that it is not an ash, but I should incline rather to consider it as cataclastic than pyroclastic.

We may now sum up generally the whole of the evidence afforded by this basic volcanic series, and see what results it leads to, and in what respects the rocks agree with the Darang series.

(1) The flows are massive towards the centre, and foliated or cleaved at the upper and under surfaces. From the evidence of the amygdules these structures seem to be due to pressure acting on the rock through long ages after it had cooled, and not to be due (at least mainly) to differential motion of the particles by fluxion.

[1] Using the terms lately proposed by Mr. Teall, Geol. Mag. Decade III, Vol. IV., p. 493.

(2) The felspars in the eruptive phases of the rock are always oligoclase, clear, pellucid and twinned; and they grade upwards in size from very minute ragged needles to large microlites and micro-crystals, as the more holo-crystalline varieties are reached.

(3) The intimate structure of the foliated rock seen under the higher powers of the microscope shews as clearly as in the hand specimen its drawn out or cleaved condition by the parallelism of the felspar microlites, and the smudging out of the opacite, chlorite, and chalcedony. A final disintegrated condition of the felspar gives with the chlorite a simple chloritic schist.

(4) As the rock becomes perfectly holo-crystalline, the felspars appear (*a*) kaolinized, so as to preclude recognition by the polariscope; (*b*) changed into quartz of corrosion, with the same result; (*c*) in the pattern of quartz-pegmatoid.

(5) The green mineral in the more eruptive phases of the rock is always viridite with no action on polarized light; or some form of chlorite in fine fibrils or fan-shaped clusters, with positive action on polarized light; or occasionally epidote in minute quantities. No augite or hornblende have been detected in the rocks which possess a glassy or slightly altered glassy base. Probably much of the pale, clear viridite represents an altered condition of the base as suggested by Col. McMahon, but in many cases the restricted patches of it seem to point to a change *in situ*, from some pre-existent crystal of amphibole or pyroxene.

(6) In the holo-crystalline rocks we find the green minerals, augite, diallage and hornblende co-existing with felspars, kaolinized beyond recognition or changed to quartz of corrosion. We find opacite in pseudomorphs. Chlorite is rare along with augite, but the borders of the latter shew alteration into hornblende. Where both augite and hornblende are present chlorite begins to predominate. Diallage is present in some few specimens passing from or into augite. We seem to be driven to the conclusion, therefore, that the beginning of the green minerals in these rocks was as a chloritoid mineral and the final end of them the same. Those stages of the rock in which crystal-building was arrested by prompt cooling shew it in the ground-mass and also in lacunæ to the exclusion of other minerals; and the fully crystallized stages also shew it as the result of the breaking up of the other minerals.

(7) The Darang lavas described by Col. McMahon have therefore some points in common with these rocks as a whole, though not with any one in particular. In the first place they cannot be distinguished in the hand specimens, particularly Nos. 7 and 11 of his published series which shew slightly crushed amygdules. Next the large amount of viridite, or some form of chlorite is strikingly like the cases I have described. He has however found augite in the hemi-crystalline forms, whereas in this neighbourhood there is no unaltered green mineral present, save in those of holo-crystalline structure. With regard to the felspars, I think they are identical, at least in the more eruptive phases of the rock. Col. McMahon names the felspars of No. 1 of his Darang series labradorite, but in sections I had made of this rock and of No. 2 of the same set the microlites extinguished under crossed nicols at a very small angle with their sides, certainly not more than 3°, which is a characteristic of oligoclase. The almost simultaneous extinction of the twinned halves also bears the same interpretation.

(8) Owing to the evident change which has been induced in all these rocks by

permeation of acid waters, which has saturated them in places and left them intact in others, but little reliance can be placed on data derived from their specific gravities and percentages of silica.

(9) With regard to the stratigraphical classification of these volcanic strata, I can do little beyond throwing out a hint, that their wide extension, apparent great thickness, and general resemblance to the Darang and Bombay basalts, should make us look towards the corresponding great thickness of the lava-fields which form the Deccan in Peninsular India for their most likely equivalents. This would make them about cretaceous in age; and if the massive limestone which underlies them corresponds to the massive limestone which underlies the Tál beds in W. British Garwal, this conclusion is further warranted by the mesozoic age of the fossiliferous Tál beds.[1] There are some difficulties, however, in the way of this correlation—their possible equivalence with the Chakratas in Jaunsar being one—so that I do not think it worth while developing the idea any further at present.

PART II.

PINDWALNI ROCK.

I will now pass on to mention a rock which I am grouping next these basic lavas, although it is completely isolated from them, occurring in fact, among the Dudatoli schists, and although it is perfectly holo-crystalline and of a still more basic character than they. I have called it the Pindwalni rock, as it is exposed very near the village of that name distant 4¾ miles north 35° west from the north peak of Dudatoli (10,188 feet). I came across this rock loose in stream-beds many times before I could trace it to its home, notably as pebbles in the Chifalghat or west Nyar river near Paithana; in the Pindwalni stream; and in the small streamlet south of Bhalson opposite Bani Thal. *In situ* I eventually found it 2 miles south-east of Khand M., on the Chifalghat, and about ¾ mile south-west of Bhalson. It is there in the form of a thin dyke (30 feet ?). Occurring in this region it is of interest as being very analogous to the so-called dolerite of the Chor, and I shall shew later on that its mineralogical composition is very probably almost identical with that rock, as described by Colonel McMahon.[2]

No. $\frac{7}{416}$ *near Pindwalni.*—A very dark greenish rock exceedingly tough and difficult to break with the hammer. Sp. gr. 3·01. Contains 40 per cent. of silica. The low percentage of silica in this rock and its high specific gravity prepared one to expect the presence of either anorthite or labradorite as the felspar representative. Under the microscope this is found to be the case, the rock-slice appearing as a holo-crystalline mixture of clear pellucid labradorite crystals, elaborately twinned and full of small crystallites; together with a pale yellow mineral, in small quantities; and a darker greenish mineral, generally decomposed beyond recognition into a chloritoid result. Titaniferous iron is also present. Taking the last mineral first for consideration, it is found largely represented either in irregular grains of opaque black material, or as skeleton trough-like forms, roughly hexagonal, with growth or decay lines crossing one another at angles of about 72° Among the six

[1] See Rec. G. S. I., Vol. XX, p. 34.
[2] See Rec. G. S. I., Vol. XX, p. 113.

sections, I had made of this rock, I found occasionally a bordering or striping of the mineral with a neutral tinted substance, which is probably the unknown leucoxene. Deep amber-coloured sphenes of small size are also fairly numerously dotted about in one section.

The other minerals in the rock are hornblende, very much altered; augite in small quantities; and mica, which last is only found in one section. The hornblende was for a long while undistinguishable, as several of the prepared slides shewed too much alteration of it into a chloritoid mineral. Eventually one of the sections gave a number of slightly dichroic brownish-green irregular forms, among which those with a prominent cleavage in one direction made extinction angles of 20° and under, with the cleavage; and one displayed a basal section with two sharply marked cleavages exactly at an angle of 124° with each other. Generally, however, the hornblende is so wholly altered as to have nothing but an aggregate effect on polarized light after the manner of radiating groups of chlorite. The augite is a very pale brownish yellow in colour shewing no dichroism. It possesses ragged outlines and is usually set in a mass of hornblende or altered hornblende. There were no sections characteristic of augite, but its scaly surface, numerous cleavage planes and brilliant polarization colours seem to indicate this mineral unmistakably. It seems extremely probable that the augite was the first and original green mineral in the rock, and that it was first altered into hornblende and that in turn altered into chlorite. Numerous sections bear out this view, for the cleavage lines in the pale nearly colourless augite run undisturbed into the dark brownish-green dichroic hornblende; although the minuter structure of the mineral, including its colour does not fade away from one to the other, but is very abruptly marked off (see diagram II, 8).

The most interesting mineral in the rock is the labradorite. It is coloured a pale warm drab of lighter and darker shades melting into each other. It occurs in very beautiful twins chiefly after the albite pattern, associated also with pericline twins. Carlsbad twins seem also to be combined with these in many cases, as indicated by the change in the direction of the indistinct basal cleavage on each side of the twinning line. Numerous examples of the albite twin when hemitrope in the zone at right-angles to the clino-pinacoid, shewed angles between the two extinctions on each side of the twinning line from 38° to 63°, the values 50°, 53°, and 55° predominating. In rectangular sections with two very distinct cleavages nearly at right-angles to each other there was once visible between the two hemitrope extinctions an angle of 62° which is the greatest possible for labradorite. There were none exceeding this so that the mineral cannot be anorthite. The polarization colours are blue-grey and pale yellowish-brown, and they have a very clear definition in nearly all cases. No kaolinisation whatever of the felspar has taken place, except as exhibited in one section, where curiously the hornblende is better preserved than usual.

A striking feature in the labradorite is the innumerable small clear crystallites which throng it. In most of the plagioclase sections they seem arranged as irregularly as a pack of cards thrown on the floor, but in some few they are gathered along definite lines either parallel with the sides or the cleavages of the labradorite. They are clear, pellucid and colourless, and possess a fine, but distinct outline. Their

shapes are slightly elongated prisms, rhombs, hexagons, and rectangles (see diagram II, 9). Some appear to have no action on polarized light, others have a feeble action, the colours being pale blue-grey and yellow, but quite independent of those of the labradorite in which they lie. In some cases they are scattered sparsely, and in others they are packed into dense masses so as to slightly obscure the natural appearance of the felspar. They shew no internal structure such as cracks or cleavage. They do not stand out with the characteristic relief, nor have they the jointed appearance of apatite: some few long, jointed prisms of apatite, actually present in the slide, rendering this contrast the more striking. They are entirely confined to the felspars and may probably be tridymite, developed along the cleavage planes, after a habit which tridymite is known to affect. The presence of undoubted tridymite in slice No. $\frac{7}{787}$. lends support to this idea, and favours the theory of its secondary origin.

There is no free quartz in the rock-slice as would be expected from its low percentage of silica: a percentage which also makes it difficult to understand even the presence of the tridymite, although doubtless the thinness of the shapes prevent their aggregating very much. In this connection its presence at all in such rocks as the Limeri rock (No. $\frac{7}{787}$) is remarkable, as it is generally wanting in all basic rocks.

I have not seen anything that I could with certainty call olivine in the rock. One or two small isolated pale minerals which I have classed with the augite may possibly be olivine, but I am inclined to think that it is altogether absent.

The specific gravity of the rock: the peculiar colour of the felspars which cannot be resolved under the higher powers of the microscope into any thing more than a faintly striped appearance: their regular shape: their belonging to the labrador species: the irregular ground-work of augite and hornblende in which they lie: the clearness of the twins, and the forms of the twins: the forms of the black mineral in large decomposed or replacing crystals, and the change of it partially into leucoxene, all seem to correspond in a marked way with the described structure of the dolerite of the Chor.[1] The main difficulty in the way is the apparent absence, in the specimens from the latter place, of the supposed tridymite in the labradorite. Still that mineral may be the effect of local schillerization in this particular area.

This Pindwalni rock, as I have already mentioned, is typically perfectly massive without any parallelism among its parts. At its upper and lower surfaces however it becomes foliated in the same way as the gneissose granites and the basic lava flows do. It was unfortunately impossible to obtain a specimen of the foliated portion *in situ* for slicing sufficiently undecomposed, so that the next specimen to be described had to be collected in the stream-bed south-west of Bhalson. As this stream is very small and the Pindwalni rock crops out in its upper part, I think there can be no reasonable doubt that it is really derived from the same bed as the Pindwalni rock, but at one of its surfaces. In addition it may be mentioned that the ordinary Pindwalni rock was scattered about in the stream in the immediate neighbourhood.

No. $\frac{7}{798}$. *Stream south-west of Bhalson.*—A black and white foliated rock. Under the microscope it is seen to be very well foliated indeed, and to consist largely of layers of quartz and felspathic material interbanded with layers of a decomposed greenish

1 See Vol. XX, p. 114.

mineral either hornblende or mica. Eyes of felspar are seen much drawn out, crushed and corroded, so that they have a granular appearance especially towards the drawn out ends of the eyes. Under the ¼ inch objective by ordinary light this corroded or crushed structure is invisible, but there is seen on the other hand very prominently a number of included clear crystallites of exactly the same shape and arrangement as in the felspar of the Pindwalni rock. The crushing and corrosion of the felspar has of course obliterated all signs of twinning.

A very marked feature in this rock is the black mineral which is in irregular grains surrounded by quite a thick border of leucoxene of dark neutral grey colour, shaded towards the borders, and with a faint aggregate polarisation.

PART III.

SCHISTS AND GNEISSOSE-GRANITE NEAR HANSURI.

I now pass on to describe a few typical specimens taken from the schistose series and gneissose granite on the south side of the Dudatoli area. In section I of these papers I gave a general idea of these rocks viewed macroscopically, and a more circumstantial account of their field relations. The following notes will therefore strictly concern their structure under the microscope.

No $\frac{7}{806}$. *Stream below Kainur.*—Garnetiferous mica-schist of the most thoroughly crystalline type. Under the 1 inch objective the mass of the rock is seen to be made up of clear quartzes polarizing in very clear and fairly vivid colours. They have the usual granular structure belonging to a thoroughly crystalline schist, that is to say, the grains with irregular outlines, only sometimes visible by ordinary light, shew, when the nicols are crossed, intricate, curved boundaries between differently coloured crystalline portions. The quartz layer as a whole is traversed by very many irregular cracks which cross from one to another of the differently polarizing grains. There is thus no residual sedimentary structure visible, no worn grains suggesting an original deposition by aqueous causes: or in other words the quartz must have been at the period of its metamorphism in such a state as to allow free play for the molecules to arrange themselves into crystalline portions, the formation of one portion being only interfered with by the formation of its neighbour, or by the other crystalline ingredients in the rock.

The mica of pale brown and brownish-yellow colours is seen distributed in plates and irregular grains generally parallel with the foliation. They shew no cleavage. White mica is also present running in long lines and possessing a very noticeable cleavage.

Sharply marked off from the other constituents of the rock are the garnets which are pale claret coloured with a very well marked raised outline. Their forms are irregular polygons, generally more or less rounded. They are perfectly intact without any breakings or tendency to be drawn out or cracked, as in the case of the St. Bernard rock. In this respect they differ entirely from the garnets present in the "gneiss-granulitique" of the snowy range at Kedarnath, which are of a ragged, shred-like aspect as though merely filling interstices among the other minerals. The garnets are of several sizes, though there is a general uniformity in this respect among the majority of them. A few very minute ones are just discernible under high powers (¼ and ⅛ inch objectives). Within each of the larger garnets, which is of course

dark under crossed nicols, there shew up a large number of irregular cavities and included portions of other minerals. Towards the centre of the garnet these are quite dense, whilst the outer border of the garnet is quite clear. The cavities are chiefly gas cavities of oval, lenticular, and irregularly amœbiform shapes, only rarely shewing polygonal outlines approximating to the shape of the garnets, and herein differing again from the rocks at Kedarnath in which the garnets shew this structure conspicuously. The gas cavities are distinguished by their black borders which shade away gradually. There are other irregular inclusions devoid of crystalline shape which shew feeble colours under polarized light, and must consequently be some included crystallite. Opacite in irregular strings and blotches is also included with them, and occurs nowhere else in the rock. Some few inclusions with a fine outline seem to be of an aqueous nature.

Besides quartz, mica, and garnets, there is another fine fibrous mineral, clear and of pale yellow or greenish colour, arranged in brush-like aggregates and polarizing vividly under crossed nicols. The brushes of this mineral run among the other constituents of the rock. The fibres are long and rod-like, often divided across by cracks, which split them up like the usual forms of apatite or of bacteria. It is probably sillimanite. Doubtless it and the garnets and much of the mica were the last result of the metamorphism induced by the gneissose-granite of Dudatoli.

No. $\frac{7}{808}$. *From near the same locality as No.* $\frac{7}{806}$.—Whilst the latter represents more definitely a foliated richly garnetiferous schist, the present specimen is from a more arenaceous band. Under the microscope it very much resembles No. $\frac{7}{806}$ the quartz and mica being in very much the same condition except that the white mica is scarcer. The large garnets are absent, but there are a number of very minute ones in different parts of the field.

There is one mineral of faintly olive-green colour and rather dichroic, changing from a brownish to a bluish green, which under crossed nicols appeared to extinguish light only twice in a complete revolution of the stage of the microscope, *viz.*, when the long axis of the mineral, which was rod-shaped, was parallel with the horizontal nicol of the analyser. They were very small, but there were several examples in the rock-slice.

There is also another unknown mineral ramifying about in cob-web fashion, without any distinct structure, among the quartz grains. It did not seem to be perfectly isotrope, although in ordinary light it much resembled an imperfectly built garnet. Its nature I could not determine.

No. $\frac{7}{815}$. *Pokree E. Nyar R.*—This mica-schist resembles the other two specimens of this series except that it is much less well pronounced as a schist and finer grained. It has a smaller amount of mica in minute irregular grains, without crystalline outlines or cleavage, and brownish-green in colour. There seem to be no white mica and no garnets present. The quartz grains do not polarize in rich bright colours as before, but in more neutral tints, blue-grey and faint orange predominating, purples and reds being rare. Under the $\frac{1}{4}$ inch objective rod-like belonites of pale green colour are fairly numerous, and some few doubtful minute bodies which may be proto-garnets, but they have no decisive action on polarized light.

No. $\frac{7}{818}$. *Hansuri band of gneissose-granite.*—In section I, I described this rock macroscopically classifying it with the lenticular-tabular variety of the gneissose-granite. In briefly commenting on the structure I then said:—"I by no means imply

that the lenticular-tabular is necessarily an embryonic condition of the augen. It seems as likely that the reverse is the case."[1] I think I can now shew by the aid of thin slices of this rock and of the quartzite near Rudarpraeg that this lenticular-tabular structure is due rather to the coalescing by crushing of originally separate crystals of felspar and grains of quartz than to an attempt at the formation of individual crystals and grains from the primarily structureless folia. It is of the greatest importance to establish the right order in this phase of rock-structure, so as to give a rational basis for an opinion concerning the date of the foliation which has happened to nearly every crystalline rock in the Himalaya; the more so because this structure has recently been differently interpreted, and assigned as largely contemporary with the intrusion of the gneissose-granite and due to fluxion rather than to subsequent pressure. The evidence which I shall give here, and that already given in the case of the amygdules of the Sirobagar lava-flows, leaves, however, no doubt in my mind that it is a super-induced phase, having no reference to flow-structure, and which may have happened at any time subsequent to the cooling and consolidation of the rocks in which it occurs.

The first section I had made of this rock shewed the peculiarities represented in diagram II, 10. I examined it first by the eye with reflected light alone, in a fairly thick slice, and then with the hand-lens, and was able to make out the following:—A and B represent two crystals of orthoclase in the shape of eyes which are united together by a connecting portion *xy*, forming altogether the prevailing lenticular-tabular structure. When the light was allowed to fall obliquely on the rather thick section, the twinning of the two felspar eyes was most manifest. The portion *a* was more illuminated than *b* and *a'* than *b'*. The bridge *xy* shewed no twinning nor extra brightening of the felspar: it had a rough and crushed look. Thus although superficially the felspathic layer seemed homogeneous along its whole course, this experiment shewed that there was a radical difference between the eyes of felspar A and B and the felspathic material *xy*, such a difference as would be implied by two original crystals A and B having been crushed into each other or over each other, the debris of the crushing going to form the bridge *xy*.

Seen under the microscope the evidence is amplified by the greater power of detecting the individual portions of the felspar which have become detached from the original crystals, and which lie embedded amongst granules of quartz. The crystals of felspar present a very much dappled and altered appearance, but they shew characteristic cleavage and polarize in their different tints as a whole and display twinning on the Carlsbad pattern. They are thus sharply marked off from the debris of quartz and felspar which fills in the bridge *xy*. It is thoroughly seen what a ragged, broken edge the felspar has, how it is torn into shreds and mechanically corroded, worse than a crystal of quartz or felspar in a rhyolite. Any one examining this rock and observing how the complicated and beautiful structure of the felspar has been battered and buffeted, would be as incapable of believing that a granitic rock was being evolved under these conditions, and that felspar was being aggregated into orderly crystals out of this chaos of remnants, as he would be on seeing the fragments of a beautiful vase of imagining that they were the constituent elements out of which such ornaments were ordinarily made.

Diagram III, 11 represents a portion of this rock as faithfully as I can reproduce

[1] Vol. XX, p. 139.

with the means at my disposal. It is seen to be built up of layers of quartz and mica besides the lenticular-tabular felspar folia. The former constituents do not differ much in their arrangement from those in the mica-schist described from below Kainur. There are no garnets and but little opacite in the rock.

Thus, taking into consideration the fact that through the whole of the structural varieties of the gneissose-granite we have passage forms connecting the tabular-foliated with the perfectly granitic form; and that between two of this series, namely, the lenticular-tabular and the augen, the order of development has been demonstrated to be from the augen to the lenticular-tabular, we may provisionally accept as true, until the opposite is proved, the general statement that the foliation of the gneissose-granite is a structure induced on a normal granitic rock by movements of the particles of the rock over one another causing them to be crushed and their crystalline contents to be disfigured and distorted.

But it may be argued that this crushing and distortion may have taken place under half-molten conditions of the rock: it may be said that the evidence I have offered shewing differential motion of the particles of the rock would apply quite as plausibly in explaining flow-structure in a rock which contained partly solidified crystals: it is perfectly true that I have given sufficient reason for thinking the tabular-foliation to have arisen from an originally granitic state, but I have not shewn that this did not come about as Col. McMahon thinks[1] by immediate transformation of the imperfectly consolidated granitic paste into a foliated substance, by a movement akin to flow-structure having been set up in it in consequence of its having been forced into fissures among the bedded schists. In other words it is still necessary for me to shew that this crushed and foliated structure was induced on the rock *in the cold*, as a later production, perhaps a geological age subsequent to the original development of the granite. With this end in view I will describe microscopically a lenticular-tabular quartz-schist previously quoted by me in Vol XX, p. 139.

No. $\frac{7}{170}$. *N. of Rudarpraeg.*—This quartz-schist in the hand specimen can be seen to be composed of grains of quartz without any felspar or anything that would suggest an igneous origin. Moreover in some places there are pebbles, perfectly rounded by water-action as large as a hen's egg. No one would be inclined to doubt that this rock was a metamorphosed sedimentary rock. Under the microscope it is seen to be composed of lenticular-tabular layers of quartz and finely powdered quartzose and argillaceous material, with very thin streaks of micaceous material bordering the lenticular-tabular layers. These layers are seen to be composed essentially on the same plan as those in the gneissose-granite of Hansuri, that is to say, eyes of quartz form the expanded portion of the layer and fragments of the same mixed with argillaceous material bridge over the interval between the two (see diagram III, 12). The quartz under the microscope seen by polarized light is of uniform colour or of two or more colours watered into each other over the greater part of its section. But towards its borders it becomes surrounded by several rainbow halos, which become less bright as they merge into the finer material of the rock. A striation following the foliation of the rock runs the pointed ends of the eyes into the finer material gradually merging them into one another. We have the following stages manifestly indicated by the present rock-slice: (1) an original

[1] See Geol. Mag. May 1887, p. 212, and Rec. G. S. I., XX, p. 205.

approximately spherical condition of the grains of quartz; (2) a crushing and breaking up of portions of them, which are left *in situ* just as they were torn away from their parent grain; (3) a further pounding up of some of the fragments and a merging of them into the finer material of the rock; (4) a coalescing of this broken and powdered material with each end of a rounded grain of quartz to make an eye, and the concomitant development of the films of mica separating the lenticular-tabular layers.

I think no one will doubt that in the case of this rock the development of a lenticular-tabular foliation, exactly similar to that in the gneissose-granite band, has taken place *in the cold*. The only other alternative would be to accept a quartzite containing well-marked rounded grains and still larger pebbles, as a kind of igneous rock. As that alternative is impossible we must take it as proved that both structures have been produced in the cold and solid way.

In the earlier part of this paper I shewed that the foliation of the basic lavas near Sirobagar had, from the evidence of the drawn-out amygdules, been similarly accomplished since the rock had cooled and solidified. We have therefore instances in this part of the Himalaya of plutonic, volcanic, and sedimentary rocks, all having suffered this peculiar form of foliation. In other words, each of the great representative rock groups have been influenced by it impartially. We must therefore look for a far-reaching cause for this structure, and as we have seen that that cause must have been pressure resulting in crushing, we must invoke a universal pressure as the all-powerful agent: and the only universal pressure that we know of is that involved in the earth-movements which have been at work for ages building the Himalaya ever higher and higher.

REFERENCES TO PLATES.

Diagram I, 1, 2, 3. Illustrating the drawing out into shreds of the amygdules by pressure after consolidation in the Sirobagar basic lavas.

Diagram I, 4. Quartz of corrosion structure in altered diorite or syenite, from near Gwar.

„ „ 5. Diallage in gabbro, shewing characteristic cleavages in basal section from near Limeri.

„ „ 6. Basal section of hornblende in same rock, shewing characteristic cleavage at 124°.

„ „ 7. Tridymite in the same rock, filling a cavity along with radiating chlorite.

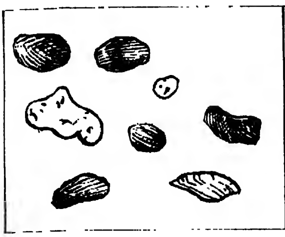
„ II, 8. *a*=augite changing into *b* a dichroic hornblende-like mineral. *N.B.* the shading in b is not intended for cleavage lines.

„ „ 9. Tridymite (?) crystallites developed in Labradorite of the Pindwalni rock. *d*=a massing of the crystallites along a cleavage crack.

„ „ 10. Lenticular-tabular structure as seen by the eye alone in a thin slice, Hansuri band of gneissose-granite: for reference see letter-press.

„ III, 11. The same rock under microscope with crossed nicols. References the same as in 10. *c*=mica layers; *d*=quartz layer.

„ „ 12. Lenticular-tabular structure in quartz-schist near Rudarpraeg; with crossed nicols.



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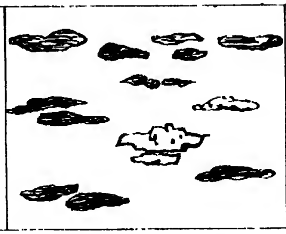

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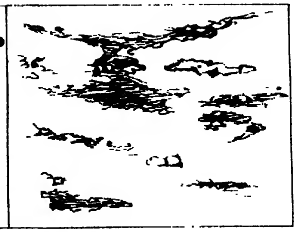

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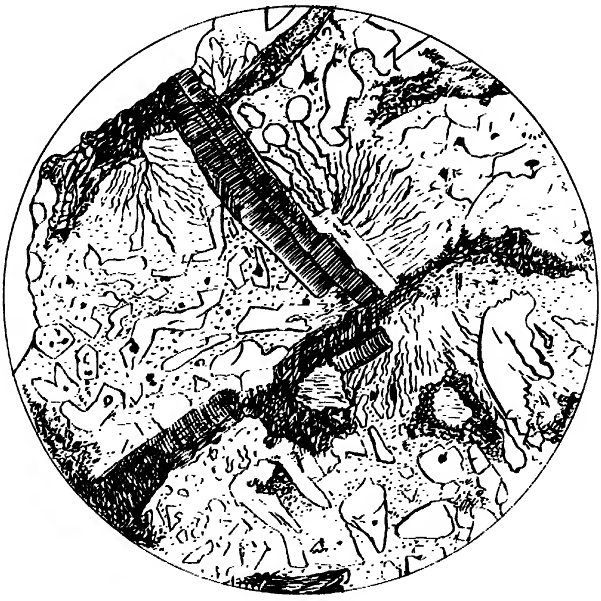

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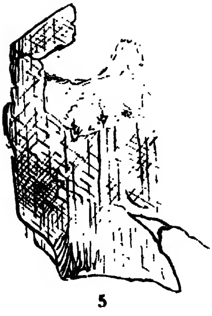

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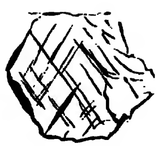

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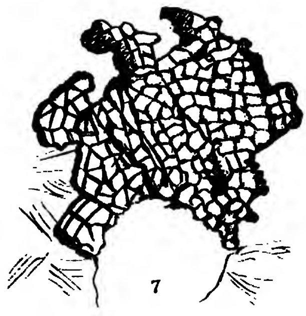

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DIAGRAMS. I.

Middlemiss.

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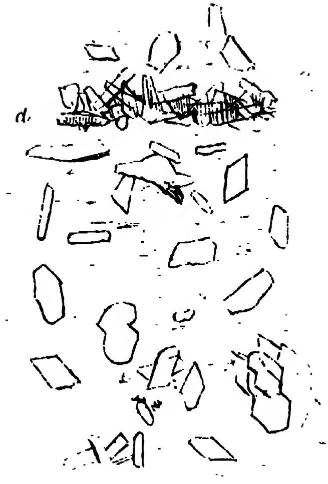

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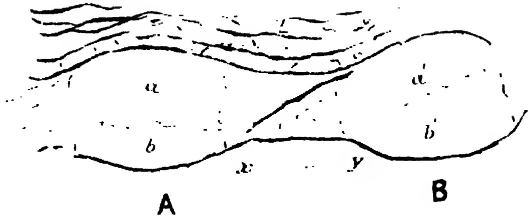

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DIAGRAMS II

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12.

DIAGRAMS. III

The Birds-Nest *or* Elephant Islands, Mergui Archipelago. *By* Commander ALFRED CARPENTER, R.N., H.M.I.M.S., *S.S. "Investigator."*

This remarkable group, called by the Burmans Ye-ei-gnet-thaik (lit. sea birds' nests) is located on the south-east side of Domel Island one of the largest of that chain forming the Mergui Archipelago at the southern extreme of British Burma. It is a small group of 6 marble rocks, the highest and largest of which, 1,000 feet in altitude, and about one mile in length, is oval-shaped and rises very abruptly out of a depth of only 5 fathoms.

They present a very striking appearance, particularly if the weather is hazy, when they are not seen until within five or six miles; for then they gradually loom out through the mist like some huge mishapen monsters that have strayed away from civilization.

Their sides are partly clothed with vegetation wherever a break in the limestone has left a cleft in which moisture and dust can lodge. Conspicuous because of its leaning attitudes is a species of tree fern which appears content to grow at any angle, but only above a height of 200 feet from the water.

The face of the rocks is reddish, partly from weather and partly from soil; and where cliffs exist the most beautiful though uncouth stalactitic formation is at work, shewing grotesque and snake-like patterns varying in hue and shape, till one feels as in some ogre-enchanted land. But the great feature of the group are the birds nest caverns which, as a rule, open into the sea, the entrance being below high water mark; fortunately I visited them at spring tides and had plenty of leisure to examine each cavern in two days' low waters.

At the south end of the largest island stands a ninepin of grey marble, 370 feet high, almost separated from the rest. It is hollow like a huge extinguisher, and the polished light blue and light yellow sides of the interior seem to point to its having been hollowed by the swell of the sea, which on entering the cave would probably expend its force vertically, the mouth of the cave being open to the direction of the strongest seas.

This ninepin forms the western point of a nearly circular cove 360 yards in diameter which runs back into the big island, and the sides of the cove rise steeply though not perpendicularly from it. At the head of the cove is a perpendicular wall of rock over which can just be seen the 1,000 foot summit in the distance.

At half tide a tunnel opens under the wall of rock at the head of the cove, and a canoe can go through; but it requires to be within an hour of low water springs for a ship's gig to go through. This tunnel has a roof-covering with large stalactitic knobs, except at its narrowest part where it is apparently scoured smooth by the action of the tidal rush. It is about 250 feet long and 4 feet deep at low water, the rise and fall being 16 feet, and is covered with dripping marine life, corallines, small corals, comatulæ, sponges, and sea-horses. Passing through this submarine drain one emerges into another circular basin with perpendicular sides, which gives the impression of volcanic action, so like it is to a crater. This basin is only open to the sky; caves here and there open into it, some of which may perhaps lead by long tunnels to other basins. Water was running freely into it from the foot of the cliffs

in several places as the tide fell, shewing that water-spaces existed, and strange gurgling sounds, as of air taking the place of water, could be heard now and again. The first thought that strikes a European is "what a famous place for smugglers." There were hardly any signs of the place being utilized, except here and there the worn ropes of birds' nest climbers. It was either not the season for the swallows or they had deserted the islands, for none were seen. There was a little reddish guano in some of the caves. There was evidently but little traffic through the tunnel by which we entered, for the delicate growth on its sides was hardly injured.

On the west side of the northern large island a lofty cavern opens at half tide into another nearly circular basin of about the same size as that we have just described, but in this case the basin also opens into the sea on the east side of the Island. After contemplating the cliffs that surround these basins, and the general circular contour of the high ridges of these islands, and the undermining action of the sea at the water line, causing in some places an overhanging of 20 to 25 feet, and the softening of the marble surface of the cavern roofs by moisture; the impression gradually forces itself on one that these circular basins were themselves at one time the floors of huge caverns, and that in days gone by the islands were far higher, with cavern piled on cavern, and that the work of disintegration by moisture is slowly going on, pulling down these marble monuments of a giant age.

Indeed, here and there a fall of blocks has occurred lately, and from there being no shoal off the base of the slip the dissolving action, if such really occurs, must be rapid. 114504

A small oyster covers the rocks at the water line. A handsome kingfisher was secured and sent to the British Museum. A few doves and an eagle or two were the only other birds seen, besides a small bat in the caves. By the position of the nest seekers' ropes, the swallows appear to build only on the roofs of the caves. The Islands appeared to be entirely composed of a blue tinted marble.[1] A vessel could be alongside them and lower the cut blocks straight into her hold, but it is probably of too poor a quality to be worth shipment.

Memorandum on the results of an Exploration *of* Jessalmer *with a view to the discovery of* Coal, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

1. On taking up work I marched in the first place to Báp and commenced an examination of the country in that neighbourhood and to the north. I found that the boulder beds cropped out to the west of Báp, extending further in that direction than I had thought probable, and that they are there associated with a great

[1] Two specimens of the limestone have been sent to the Museum by Commander Carpenter; they are a very pure pale grey-coloured massive sub-crystalline carbonate of lime: in fact a marble, which if obtainable in fair-sized pieces would do for use or ornament where the colour is not objectionable, as for flags, wash-hand stand and table top.

development of dark red clays and shaly sandstones for the most part impregnated with salt.

2. To the northwards I traced the boulder beds as far as the limit of Jessalmer territory, beyond which they do not appear to crop out at the surface; and to the southwards I believe I have traced their utmost extent.

3. As remarked in my former memorandum,[1] this country is very unfavourable for geological observations, but I had no conception of how impossible it is to make a satisfactory detailed geological map until I had made the attempt. In the immediate vicinity of Báp and the Sird villages there are stream beds which do to a certain extent exhibit the rocks, but for the rest there is nothing but a vast undulating plain of sandy soil in which the underlying rock is represented by patches, varying in size, of pebbles, fragments of ferruginous sandstone or of concretionary limestone. Under these circumstances it is impossible to satisfactorily determine the true relations of the rocks, but one or two points stand out with some clearness.

4. First among these is the fact that wherever the rock immediately overlying the boulder beds is seen it is a hard, black ferruginous sandstone, with or without pebbles; it might be supposed that this indicated a conformity between the boulder beds and the ferruginous sandstone, but it may be, and probably is, merely due to the fact that, except where hardened by impregnation with iron, the sandstones do not shew themselves distinctly at the surface. Under these circumstances there is no proof that the different exposures of the black sandstone represent the same horizon, and it is by no means impossible that the boulder beds are unconformably overlaid by sandstones of upper gondwana age.

5. In the neigbourhood of the village of Akhádana there are some indications that such is the case. Here there are some low, rounded ridges, covered with shingle, in the hollows between which the boulder-bed is exposed. The matrix of the conglomerate from which the pebbles are derived is not as a rule to be seen, but, where this is a sandstone ot the black ferruginous type, it occasionally crops up through the surface wash of shingle and the transition from the boulder beds with numerous large unrounded fragments of red syenite and malani porphyry to the conglomerates, in which these rocks are barely represented and then only by small rounded pebbles, is so abrupt as to suggest an unconformity.

6. If this be so, there will be but little use searching for coal in this neighbourhood, and there is another fact which points to the same conclusion. At Akhádana a well has been sunk which originally reached a depth of 380 feet but is now nearly filled up; to judge by the debris excavated, this well appears to have been sunk through red sandstones of Vindhyan type with the exception of some 70 feet or so (14 *purus*) which was in pebbly sandstone; but as the well is lined with masonry throughout the portion still open, I was compelled to trust to native information and an inspection of the waste heap.

7. This indicates that the very irregular junction of the Vindhyans and newer beds noticed further east extends for some distance to the west, and any borings put down here would be more likely to strike Vindhyans than coal, at a moderate depth.

[1] R. G. S. of I., XIX, p. 122.

8. I made a short tour into the sandy desert towards Bîkhampur in order to see whether the rocks exposed in the wells gave any indication of the presence of coal measures; though I visited two wells in course of construction, I was not fortunate enough to find any fossils, and the rocks were all of a type very similar to those seen among the upper Gondwanas of Jessalmer.

9. Having examined this district, sufficiently to see that no promise of coal could be obtained, I marched towards Jessalmer, intending to visit the reputed coal at Hamira, and then try the unknown country south of Jessalmer. The so-called "coal" of Hamira I found to be merely isolated trunks and fragments of fossil wood in which the structure was still quite distinct; owing to its lightness and the abundance of pyrites, this would be of very little use even if it occurred in quantity, but, owing to its mode of occurrence as fragments scattered through a sandstone matrix, it is quite useless.

10. To the south of Jessalmer I found a descending series of sandstones, in the upper portion of which hard ferruginous bands and patches were abundant, extending as far as Dévikot. To the south of this the beds must turn over, for at Vinjorai ferruginous sandstones again appear and form prominent scarps, here however with a southerly dip.

11. The rocks near Dévikot are, for the most part, a red sandstone, not unlike some of the sandstones near Nagore, but the frequent occurrence of spherical concretions, the general softness of the rock and above all the occasional occurrence of hard ferruginous bands leave but little doubt on my mind that they belong to the Gondwana series. It is impossible to say whether the red colour is original in the rock or merely due to its being formed of the debris of the presumed Vindhyan sandstones; if the former be the case it may indicate the proximity of the red rocks associated with the Bap boulder beds.

12. Hearing that rock was exposed in many places along the eastern frontier of Jessalmer south of the Jessalmer-Pokran road, I examined these outcrops which proved to be nearly all conglomerates and sandstones of unknown age, but as the crystalline rocks appear to be nowhere far from the surface and repeatedly crop out, it would under any circumstances not be advisable to put down borings on this line of country. To the west, rocks are said to be all hidden by sand until the exposures between Jessalmer and Vinjorai are reached.

13. From Jessalmer I crossed over to Pokran to try what might be found there, and was somewhat surprised when a detailed examination of this tract convinced me that the boulder beds there pass under the dark red sandstones which have been regarded as of Vindhyan age. There is no direct proof of the age of these sandstones, nor was I able to determine whether the boulder beds of Bap and Pokran were the same or different, but there seems little room for doubt that the red sandstones of Pokran are continuous with those of Loháwat and overlie the Vindhyan limestone.

14. Towards Jodhpur sandstones, which may or may not belong to the same series as those of Pokran, are largely exposed; frequently they are dark red, composed of well-rounded grains of quartz, but just as often are paler red and by no means infrequently white, the latter beds being usually as hard as the sandstones of Khátu. These latter frequently weather with small rounded bosses and occasionally

include thin bands of black ferruginous sandstone like that seen among the upper gondwana sandstones of Jessalmer.

15. These sandstones have previously been regarded as of Vindhyan age, but if they belong to the same series as the sandstones of Pokran, and if the Pokran boulder beds are the same as those of Báp, they must be much newer than Vindhyan, and might be of lower gondwana age. It is impossible to determine this point with certainty, but the balance of evidence appears to me very strongly against regarding the Jodhpur sandstones as of gondwana age; nor if this could be granted does the prevalence of red beds hold out any promise of the existence of workable coal.

16. It will be seen from the above statement of the essential facts that the prospect of finding workable coal is very small. Along the eastern boundary of the gondwana area upper gondwanas appear to rest unconformably on the boulder beds or even on the old crystalline rocks; there is no reason why the coal measures should not be present, hidden by upper gondwanas and recent sand, but any search for them would be purely speculative. Still, seeing the enormous value that would attach to any deposit of workable coal in this region it may be thought advisable to institute a search; in this case the best plan would be to sink a boring on the crest of the anticlinal between Jessalmer and Vinjorai, about 3 miles south of Devikot, where older beds than are seen to the north or south are exposed; it would be necessary to push this boring to as great a depth as possible or until the crystalline floor was struck.

17. I may point out that as yet only those localities which appeared most promising have been examined; that there is still a considerable area of rock country which has not been visited as the rocks are almost certainly of upper gondwana or even later age, and the discovery that the Pokran boulder beds underlie the sandstones of the Pokran scarp opens out a vista of possibilities which certainly deserve more thorough working out than I was able to give them at the tail end of the working season.

P. S.—Since writing the above I have had an opportunity of examining the rocks of the Salt-Range. Here there is a considerable series of rocks, known as the speckled sandstone group, at whose base there is a boulder bed precisely similar to, and probably the same age as that exposed near Bap. The rocks overlying it are very similar to the neozoic rocks of Jessalmer, except for the absence of the black ferruginous sandstone so common in the latter locality; in spite of this, the lithological relations of the Jessalmer beds with the Speckled sandstone of the Salt-Range are much stronger than with the gondwanas of the peninsular. In the speckled sandstone the only traces of coal known are a few thin papery layers of coaly matter, and it is very probable that there is a similar absence of coal in the Jessalmer rocks. In the absence of special search there can be no certainty on the subject, but, as before remarked, search would be speculative to a degree. I cannot say that there is no coal in Jessalmer, but that is the extreme limit my observations allow me to go to.

CAMP, SUTLEJ VALLEY;
The 31st May 1887.

A Facetted Pebble *from the* Boulder Bed, ("Speckled Sandstone") *of Mount Chel in the* Salt-Range *in the Punjab, by* DR. H. WARTH.

(With 2 plates.)

Amongst the facetted pebbles which I found in the Salt-Range is one with such a large number of polished surfaces and such distinct ice scratching that it deserves special description.

The annexed diagram[1] represents two opposite views of the pebble in natural size. The view on the right hand shews the largest of the polished surfaces, which is 10 centimeter's long and 5 centimeters broad. The number of faces is about 20 all counted, the very smallest being about 1 centimeter long and half a centimeter broad. The diagram shows the direction of the scratches on all the faces. The scratches are thicker on the right side of the faces, showing that the stone moved from the left to the right along the respective faces. The pebble must have been pushed by the ice along the floor of the glacier bed, and the whole movement may have lasted several hundred years; the stone during the time turning round so that the polished surfaces were necessarily produced. The angles between the faces vary considerably, and the stone moved also from side to side, so that it did not revolve regularly. But generally speaking it revolved in the mean round the axis A-B of the drawing. The direction in which the stone revolved was most probably such as would make it roll forward, and therefore on the diagram from left to right. Very likely only one total revolution took place during the whole passage of the stone under the glacier, and the faces took therefore each a very long period to form. About one-fifth of the surface is unpolished. The pebble weighs 680 grammes. The rock is red porphyry with a specific gravity equal to 2·566.

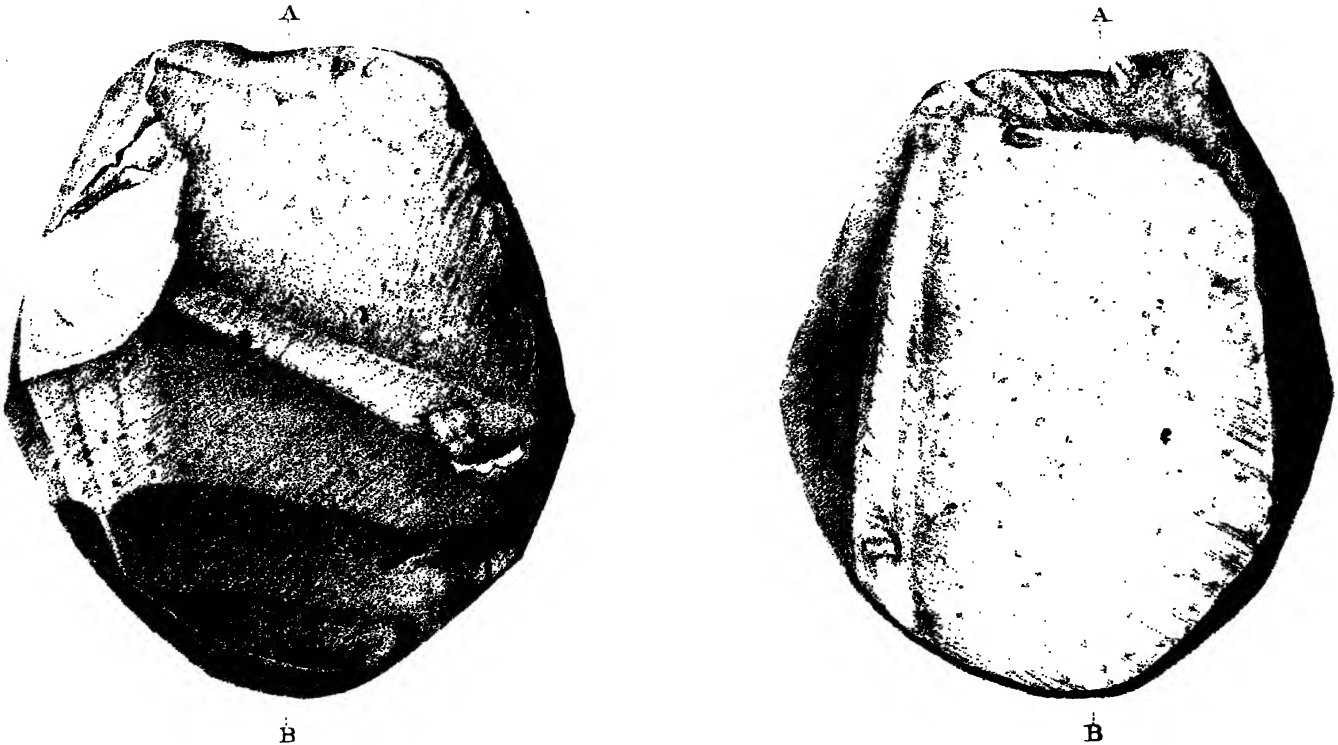
The pebble was obtained from the crystalline-boulder bed near the summit of Mount Chel. This mountain rises from the plateau of the eastern Salt-Range to a height of 3,700 feet. Magnesian sandstone forms the summit, but the crystalline-boulder bed which rests here directly on the magnesian sandstone comes close to the summit on the north-eastern slope. The actual boulder-bed, some feet thick, is accompanied by at least 25 feet thickness of greenish mud throughout which boulders are also scattered. The boulder-bed is exposed in section and also parallel with the surface. The surface exposure is more considerable. There is a large mass of boulders and pebbles scattered over several acres of surface on the actual site of the boulder-bed overlying the magnesian sandstone. Only the individual boulders and pebbles have been slightly shifted and re-arranged after the weathering away of the mud. It is on this area that I found about a dozen facetted pebbles, besides many other pebbles and boulders which had only one glaciated surface. I do not remember finding a facetted pebble on the outcrop of the vertical section of the boulder-bed, but this is only natural. When there is only one facetted pebble, amongst

[1] The sketch is very diagrammatic; the scratchings being indicated by very much broader lines than appear on the facets of the specimen; though the actual scratches are very clear and distinct. The second plate is a fairly accurate drawing.—*Ed.*

Facetted

DIAGRAMMATIC

Warth, Facetted Pebble



DIAGRAMMATIC

PLATE II.

perhaps a thousand others, a large surface is required for search if the search is to be successful. I picked up the specimen under description with my own hand from the area of scattered pebbles. I consider it as a genuine specimen produced by glacier action, deposited by ice transport amongst the boulder-bed, and exposed on the breaking up and weathering of this bed *in situ*. If it was thought possible that a man would have shaped this hard porphyry and thrown it amongst the pebbles, how can we account in the same way for all the other specimens and the partly facetted ones here and in other parts of the Salt-Range. One and all must be the work of nature.

Examination of Nodular Stones *obtained by trawling* off Colombo, *by* E. J. JONES, A.R.S.M., *Geological Survey of India.*

The following acccunt[1] of these stones is reprinted from the Journal of the Asiatic Society, Bengal, as being of more direct interest in these Records:—

"The nodules were obtained during a trawling operation off Colombo in water of 675 fathoms, and are stated to have been found associated with sand and mud, which formed a hard calcareous crust at the bottom of the sea, and a small quantity of which was forwarded with the specimens.

"The stones are irregularly rounded, and vary in shape from almost spherical to roughly cylindrical with rounded ends. The specimens received varied in size from 1—4 inches in length and 1¼—¾ inch in thickness. Externally, they are rough and mostly have one or two small excrescences of the size of a pin's head, and a few small pittings of about the same size; the colour is dirty light grey.

"On breaking them open, the fractured surface has much the appearance of an ordinary slate without the cleavage, and is of a much darker colour than the exterior. Running along the central line of a long cylindrical one which I broke open, there is a narrow vein of a brownish colour.

"A microscopic examination of a thin slice shewed merely a confused mass of aggregates resembling in their structure that of sphærulites, such as occur in the so-called sphærulitic lavas, with the remains of Foraminifera and Radiolaria disseminated throughout the mass. With ordinary light, little is to be seen except more or less radiating fibrous aggregates, but, as soon as the section is observed between crossed Nicol's prisms, the whole field is seen to be covered with little dark crosses

[1] Natural History Notes from H. M.'s Indian Marine Survey Steamer 'Investigator,' Commander Alfred Carpenter, R.N., Commanding. No. 5. On some Nodular Stones obtained by trawling off Colombo in 675 Fathoms of Water.—By E. J. Jones, A. R. S. M., Geological Survey of India. Journ. Asiatic Society of Bengal, LVI., Part II, No. 2, 1887.

with their limbs parallel to the planes of the prisms, and, on revolving the stage, the limbs of the crosses keep the same orientation whilst the section revolves.

"It is when thus observed that the aggregates are seen to be entirely distinct from one another, as each cross keeps to its one aggregate, and the crosses do not overlap; so that, by revolving the stage, the limit of each aggregate can be determined by tracing the path of the outer end of one of the limbs of the crosses.

"In the volcanic rocks in which this structure is known, it appears to be due to incipient crystallization in a glassy mass; and at first it might be supposed that these masses were of igneous origin. This idea, however, is untenable on account of the remains of Foraminifera (of several species, the most easily recognised of which are the globigerinæ) and Radiolaria which are sparsely scattered through the mass, and, in some cases, enclose a sphærulitic aggregate.

"An indeterminate greenish substance, which probably consists of glauconite, is also seen scattered through the mass.

"The only difference that can be detected between the central vein and the portion between it and the exterior is that the aggregates in the central vein are much larger and the colour brown instead of green, and that it is unacted on by hydrochloric acid, which dissolves out some calcic carbonate from the other portion.

"As mentioned by Mr. Daly in his letter forwarding the nodules, these are very heavy, having a sp. gr. of 3·77 at a temperature of 30° C. as against water of 4° C.

"A qualitative analysis shewed the nodules to consist in great part of baric sulphate together with small quantities of calcic and strontic sulphates, small quantities of calcic and magnesic phosphates, aluminic silicate, calcic carbonate, and traces of iron, sodium, and manganese.

"Not having the time to devote to a complete quantitative analysis, I made, in order to arrive at an approximate estimate of the proportion of baric sulphate present, a determination of the sulphuric acid. An average sample from two of the nodules powdered and dried at 100°C. gave 82·5% of baric sulphate, the whole SO_2Ho_2 being calculated as SO_2Bao''.

"This result is, however, of course too high, as a small quantity of the SO_2Ho_2 is combined with Ca. and Sr. in the form of calcic and strontic sulphates, though, from the results of the qualitative analysis, it is probably not much too high; and we may, I think, safely take 75% as the percentage of baric sulphate present.

"In order to see whether the material was derived from the mud in which the nodules occur, and which also contained Foraminifera, I made a qualitative analysis of the mud, and found it to consist mainly of aluminic silicate, with small quantities of calcic carbonate, some iron, and a trace of manganese; there was also a trace of an alkaline earth which was not removed by boiling with hydrochloric acid and subsequent washing, but this, on spectroscopic examination, shewed itself to be lime.

"In spite of the negative result of the analysis of the mud, I am inclined to think, from the presence of the Foraminifera both in the mud and enclosed in the nodules, that the latter have been formed at the bottom of the sea either at the spot where they were found or at no great distance therefrom, though it is difficult to imagine how the material was obtained, but it is possible that a careful analysis of a larger

quantity of the mud would reveal a trace of Barium, for sea-water contains a slight trace of this element.

"I cannot at present call to mind any instance of sphærulitic structure occurring without the aid of heat.

"In volcanic lavas and in artificial glasses, it may be regarded as concretionary, or as resulting from incipient crystallization or devitrification around certain points or nuclei. The nuclei when they exist consist either of a granule or a minute crystal or crystallite, but most commonly no nucleus is discernible.[1]

"In this case, however, it would seem, that it must be due to slow segregative action; and, baric sulphate being very slightly soluble in water, the deposition would be very slow and may have been to some extent crystalline, at any rate sufficiently so to produce the same effect as incipient crystallization from a glassy mass.

[1] Rutley's Study of Rocks, p. 183.

yours sincerely
[illegible]

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1888. [May.

Award *of the* Wollaston Gold Medal, Geological Society of London, 1888.

Annual General Meeting, February 17th, 1888. Professor J. W. Judd, F.R.S., President, in the Chair.

In presenting the Wollaston Gold Medal to Mr. Henry Benedict Medlicott, M.A., F.R.S., late Director of the Geological Survey of India, the President addressed him as follows:—

"Mr. Medlicott,—The Council of this Society are not unmindful of the fact that many of our Fellows are engaged in the promotion of Geological Science in every part of a vast Empire; in awarding to you the highest honour which is at their disposal, they are following a precedent which was established more than fifty years ago, by the presentation of the Wollaston Medal to Cautley and Falconer. In that great Indian dominion where those famous geologists carried on their important researches, you commenced your labours as far back as the year 1854; and for more than a third of a century you have continued the almost incessant exertions which have led to very important additions to our knowledge, often obtained only at the price of severe hardships, and at the risk of serious dangers. During the last eleven years you have occupied the important and responsible position of Director of the Indian Survey; and it is to your administrative ability in that position that we owe many of the valuable results obtained by that Survey in recent years; more especially are we indebted to you, and to our Secretary, Dr. Blanford, for that useful Compendium of Indian Geology which has now become indispensable to all students of our science. We feel it to be singularly appropriate that we are able to make this award to you just at the time that you return to your native country for the rest you have so well earned."

"Mr. Medlicott replied:—Mr. President,—The award of the Wollaston medal by the Geological Society is the most gratifying distinction that a geologist can receive. It is only as a recognition of devotion to our science that I can venture to accept so great an honour. My work has been chiefly in combination with others, but it gives me much consolation to think that my colleagues of the Geological Survey of India will share in this reward, and will appreciate it."

The Dharwar System, *the* Chief Auriferous rock series *in* South India, *by* R. B. FOOTE, F.G.S., *Superintendent, Geological Survey of India.* (With Map.)

The promising development of the gold mining industry during the last five years having gone far to undo the mischievous effects of the wild gold speculation of previous years, greatly increased attention has been devoted to the auriferous rocks in Mysore, and the adjoining districts of the Madras and Bombay Presidencies and the Nizam's Dominions. A proof of this is furnished by the fact that a London publishing firm reproduced the map which I had given in illustration of my paper on "A traverse across some gold fields of Mysore," which appeared in the Records, Geological Survey of India (Vol. XV, part 4, 1882). Since the publication of that paper my official duties have taken me over large tracts occupied by the auriferous rocks both in the Ceded Districts (Bellary, Anantapur, &c.), and in Mysore; especially in the latter. Some of the information gathered about the auriferous rocks in the Ceded Districts was made public in the "Notes" published in 1886, "On the geology of parts of the Bellary and Anantapur Districts" (Records, Geological Survey of India, Vol. XIX, part 2). The additional facts collected as to the geology of the Mysore country were obtained during a visit to different parts of that State, made by desire of the Durbar with the object of my reporting on the auriferous tracts known to exist there, and about which separate reports had been previously drawn up by Messrs. Lavelle and Marsh. On completing this tour, which occupied the months of February, March, April and part of May of last year, I drew up a "Report on the Mysore Auriferous Tracts," which was published among the selections from the Records of the Mysore Government for 1887. My report was accompanied by a map showing the distribution of the auriferous rocks or "Dharwars" as then ascertained. This map, too, only claimed to be a sketch, and, as such, subject to modification when the country comes to be regularly surveyed. It was, however, a great advance on the first map published in 1882. In this report the subject of the auriferous rocks had to be dealt with from a purely economic point of view, and for non-geological readers, all technical expressions were, therefore, as far as possible banished from it, and no attempt made to illustrate the different features of purely geological interest. These are dealt with in the present paper. The map which accompanies it is on the same scale as that illustrating my "Traverse across Mysore" (Records, Geological Survey of India, Vol. XV, p. 4, 1882), and a comparison of the two will show that a very real advance has been made in the interval in ascertaining the extent and distribution of the Dharwar rocks. The map, however, is only put forward as an improved sketch to be superseded in its turn. Large additions to the extent of the Dharwar system will certainly have to be made on the map, as the geology of south and west Mysore, and the adjoining districts of South Canara, Coorg and Coimbatore is worked out. In the Ceded Districts, too, and most probably on the western side of the Dharwar Districts also, considerable areas of the Dharwar rocks have yet to be separated from the Gneissic system among which they were formerly reckoned.

The Dharwar rocks form a very well marked series (or system), consisting mainly of Schistose rocks (hornblendic, chloritic and argillitic) with associated,

more or less hæmatitic quartzites and numerous contemporaneous trap flows. In many parts of the areas occupied by these rocks occur quartz reefs and veins which are auriferous, indeed all the more important auriferous tracts as yet known in South India lie within such areas, and hence the rocks composing them have come to be called the auriferous series. The Kolar gold field unquestionably occurs in an outlying band of the Dharwar system, and so also the Honnabetta, Chicknayakanhalli, Kotemaradi, Honnamaradi, Halékal gudda, Malibennur, Chiranhalli, Honnahatti auriferous tracts and the Honnali gold field (Kudri konda and Palvanhalli) in Mysore, and the Dambal gold field, in Dharwar District, which occur in one or other of the great bands. The majority, if not all the fifteen outlying auriferous localities, forming the west central group of my Mysore Report are also situated on detached areas or outliers of the Dharwars.

The name Dharwar why selected.

The name chosen for this great series of rocks, the "Dharwars," was selected on well recognized principles of geological nomenclature, from the district in which the separation into a distinct and separate system of the Schistose rocks was first recognized. Till then they had been grouped as part of the great South Indian Gneissic system. The necessity for such separation was pointed out by me in my memoir on the South Mahratta country (Memoirs, Geological Survey of India, Vol. XII, 1876), but I waited for further evidence of the stratigraphical relation of the Schistose series to the far more crystalline gneissics, and this was obtained during my traverse across Mysore in 1881, and by an examination of the rocks in the Sandur and Bellary hills in 1884-85. The Schistose rocks are very largely and clearly developed in Dharwar District, and the well known town of Dharwar stands on them. All things considered, no other local name seemed to have so many points in its favour and the name of Dharwar was therefore given to the schistose, or auriferous rock system.

Distribution of the Dharwar rocks.

A glance at the map will explain the distribution of the Dharwar rocks far more fully than would many pages of writing. The reader is therefore referred to the map, where it will be seen that the rocks occur in three great bands, continuous for great distances, between which, and to the north and east of which, are a considerable number of irregular patches and short bands, mostly of small size, which will be enumerated and in part described further on. The three great bands have been called respectively the Dharwar-Shimoga band (the most westerly of all at present known); the Dambal-Chiknayakkan-halli band, and the Pennér-Haggari band, which includes the great Hunugunda band extending from the Tungabhadra, north-west across the Raichur Doab up to the Kistna. Between the Dharwar-Shimoga and the Dambal-Chiknayakkan-halli bands lies (on the right bank of the Tungabhadra) a large patch, at the south end of which stands the large village of Kunchur (Coonchoor); only the extreme north end of this has been actually visited; it cannot therefore be described, though the bare nature of the hills made it easy enough to see that they did not consist of granites or gneisses. In the southern part of the space between the two great bands just named lies a considerable number of small patches, mostly narrow and band-like in shape, of which three may be named as important geologically. These are the Taggadur-

The great bands.

Minor bands and patches.

betta patch in latitude 13° 3′ N.—and longitude 76° 30′ E., the Bellibetta band, 16 miles to the south, and Honnabetta 24 miles south-east of Taggadurbetta. Twenty miles south of Bellibetta lies a group of three small auriferous patches which I will call the Sonnahalli group (to be described further on), and 22 miles east of this group is a solitary small patch, at Holgere, the most southerly auriferous tract which came under my notice in Mysore. This is a doubtful outlier of the Dharwars.

The Sandur and Copper mountain tract.

Between the Dambal—Chiknayakkan-halli band and the Pennér-Haggari band lies a rather large and very important tract of the Dharwars which here form the Sandur hills and the Bellary Copper mountain range, a group of hills in which the geological characteristics of this system may be studied to great advantage.

Bands north of the Pennér-Haggari band.

To the north of the Pennér-Haggari band in the country between the Tungabhadra and Kistna, are several short but important bands which will have to be described separately further on.

Lastly, must be noticed the band forming the Kolar gold-field, which lies far to the eastward of the southern part (as at present known) of the Dambal-Chiknayakkanhalli band. When the country intervening between it and the known part of the Pennér-Haggari band shall have been examined it is very probable that a connection will be traceable between the two bands.

Of the several bands and patches above enumerated, only those lying within the Bellary district proper, and a few miles of the Pennér-Haggari band in Anantapur district have been closely surveyed with the object of specially studying their structure and petrology. The Kolar, Honnali and Dambal gold-fields have also been studied carefully, but no good maps showing their topographical features fully were available, and in the two former so much of the surface is covered with cotton soil that very many points of difficulty could not be solved satisfactorily.

Origin of the schistose bands.

The occurrence of the Dharwar rocks over the face of the gneissic systems in such remarkable bands, or portions of bands, is a feature which at once arrests the attention and demands explanation. The explanation is that the Dharwars, as now seen, are the remains of a great sedimentary series which covered a very large area in what now forms the peninsula of India. The periods of sedimentary deposition were interrupted by periods of volcanic activity during which great flows of contemporaneous trap were poured out. Many such flows were formed in different parts of the Dharwar area, as in that which now forms the Sandur and Bellary hills, and further to the south-west the hills south of Chitaldrug and the Bababuden mountains.

The Dharwar rocks were at a very remote geological period exposed to vast lateral pressure, by which they were crumpled into great folds, which were then exposed to great denuding action, and largely eroded. This took place anterior to the deposition of the Kadapa and Kaladgi basins, which belong to the upper transition group. Both basins were deposited unconformably on the upturned, and greatly contorted and eroded beds of the Dharwar system. The great jaspery hæmatite beds of the Dharwar system furnished the bright coloured jasper pebbles which are so striking a feature in the basement and othet conglomerates of the Kadapa system.

The forces which caused the great crumpling of the Dharwar rocks had, of necessity, also much effect on the underlying gneissic rocks, and in various places

induced a parallelism of folds which gives locally great semblance of conformability. The section of the gneiss rocks exposed south of the southern end of the Sandur tract, shows the gneiss to have been affected by an anterior process of crushing from pressure, acting in a more or less east and west direction. This is noteworthy, as it shows that the peninsula was affected at no less than four periods by great, approximately east to west or west to east, thrusts; the two just noted, and two later ones, by which the Kadapa and Karnul rocks were respectively crumpled up into the great foldings they now show. Of these, the last would seem to have been the least energetic.

Only a brief description of the chief petrographical characters of the Dharwar rocks can now be given; the full description of the members of the system which occur within the limits of the Bellary and Anantapur country must be reserved till the final Memoir on that tract comes to be written, while those of the Dharwar rocks lying in other tracts will have to await the times when they may have been studied by other geological workers.

DESCRIPTION OF THE SEVERAL BANDS AND PATCHES OF THE DHARWAR SYSTEM.

I.—The Dharwar-Shimoga band.

Northern group of inliers.

This great band of the Schistose rocks appears at its northern extremity (in the Belgaum District) in several small inliers exposed by the denudation of the overlying Kaladgi rocks and Deccan Trap flows. These inliers present nothing very noteworthy, and may be dismissed with a mere enumeration. They are seven in number. The most northerly is the Gokak inlier covering some ten square miles around the town of Gokak. The second, or Kelvi inlier lies about a mile south of the first. Four miles to the S. W. of the Gokak inlier is the Padshapur inlier, a rudely cruciform valley, cut through the Kaladgi quartzites. In this the Dharwars are very badly seen, owing to the extensive alluvial deposits of the small Markandi river, a tributary of the Gatprabbha. The Dharwars are similarly very badly displayed in the small inlier exposed on the north side of the valley of the Belgaum nullah (some four miles N. E. of that town), which nullah forms the most southerly branch of the Markandi river. The other three inliers may be called the Wannur, Budnur and Seedapur inliers, from the principal villages within their limits, or close to them. The northern extremity of the great band south of the edge of the Deccan trap area is also very badly exposed; the surface of the schists, and indeed of the whole Sampgaum Taluq, being greatly masked by extensive sheets of cotton soil. The rocks chiefly seen are bands of hæmatitic quartzite, forming low bare ridges, which are in many cases traceable for many miles in extent; between them are beds of chloritic schist, generally of pale green colour. Argillites occur also, and are in parts considerably hæmatitic in their mineral character. Contemporaneous trap is also to be seen in the valley of the Belowaddi nullah.

North end of the main bands.

Gold washings in Sampgaum Taluq.

Near to Byl Hongal and Belowaddi, the sands of several streams are reputed auriferous, and used formerly to be washed for gold; so also the nullah at Hatti Katti near Belowaddi. The accounts given of the amount of gold found in this quarter are rather conflicting, the earlier records representing it as much more important than at present. All the enquiries made by myself on the spot, and for me by the local authorities, showed the gold industry to be practically extinct. Extremely few traces of quartz-reefs are to be seen on cursory inspection, but the country is closely covered by cotton soil and by great accumulation of hæmatite derived from the great beds of hæmatitic jaspery quartzite which occur so numerously. I followed the Dharwar rocks from the valley of the Malprabbha at Sangoli southward to Tegur, and thence south-eastward to Dharwar town. The schists, argillites and hæmatitic bands continue all the way, and as far as the eye can reach, on either side of the road. The schistose rocks are, in their appearance, so utterly unlike the gneisses and granites flanking the great bands, that it is generally very easy to recognize the character of hills and ridges when seen in strong sun light from distances of many miles even, more especially when the ridges are continuous. The extreme bareness of vegetation of most of the ridges also greatly facilitates the recognition of geological features from long distances. The northern part of the Dharwar-Shimoga band forms, roughly speaking, the western boundary of the great black plain, the regur flat of Dharwar District. From Dharwar, I followed the band down to Hubli, and from high ground there could see it extending miles away to the S.S.E. Newbold describes a great schistose band crossed by him in travelling from Sirci (N. Canara) to Gadag (Gudduck); this can only be the extension of the Dharwar-Shimoga band. At Harihar it crosses the Tungabhadra, and from here I have either followed it personally or traced it by the eye in unmistakable beds over by far the greater part of the area which I have represented it as occupying. Some parts of it I have coloured in as of Dharwar age, from the conviction that the beds I have crossed and identified as forming the northern ends of great ridges, will assuredly be found to extend as far as those ridges are seen to stretch without any change in their physical characters and appearance. The excellent delineation of the topographical characters of such ridges in the 1-inch maps of the Topographical Survey of Mysore, assures me that my inference of such extensions of the Dharwar rocks is quite justifiable, and I feel assured that my inferences will be confirmed. This is specially the case with the tract lying between the Tunga and the Bhadra rivers. Of the southerly extension and strike of the Dharwar rocks in the great ridges south of Kumsi there can be no doubt. As seen from the Honnahatti hill, near Lakki-valli, the same characters of the continuous ridges is seen to extend far to the southward, and the same continuous character of orographic feature strikes the eye forcibly when looking south-westward from Kalhattigiri peak on the Bababuden mountain. Unless the topographical features of the mountains around Kalasi peak are utterly misleading, and from my experience of the remarkable agreement of topographical feature and geological formation over very great part of Mysore, I cannot believe that to be the case, the Dharwars extend far southward of what I have indicated, and form the

Near Dharwar.

South of the Tungabhadra.

Near Lakki-valli.

great mass of Ballalraiyandrug, and extend still further south, down into the low country of South Canara.

Gneissic inliers in the central part of the band.

The representation I have given of the Dharwar rocks around the Honnali, Saulunga, Shimoga and Tarikere gneissic inliers is, I feel convinced, a near approximation to the truth. The eastern part of the north boundary, and the southern boundary of the Honnali gneiss inlier, I lay down from actual survey. The eastern boundary is formed by bold hills whose western base must coincide very nearly with my lines. Of the Shimoga inlier, I have followed more than half the boundary lines, and the same was the case with the Tarikere inlier. To the east of the Shimoga inlier, I think it possible that an inlier, or some small inliers, may occur between Channagiri and Tarikere, and so also with regard to the tract between Belur and Banavar further to the south: but this is merely a surmise.

To the west and east of Hassan, I have shown two narrow bands of Dharwar rocks extending southward, neither of which I had the opportunity of following to its extremity. Of the extension of the western band I could not form any opinion; that of the eastern band will, I expect, be found running down nearly to the Cauvery.

From the very rapid character of my journeying over the central part of the Dharwar-Shimoga schist band (the Honnali gold-field excepted[1]) the information I gathered was necessarily fragmentary, but nevertheless it throws much light on the petrographical structure of the band, and is therefore worthy of record, and I will give my observations in geographical order proceeding from north to south.

At Harihar the Dharwars are greatly masked by the alluvium of the Tungabhadra, and by the almost ubiquitous cotton soil. Large banks of coarse shingle occur both north and south of the town. Underlying the shingle, schist crops up at intervals along the road to Mallé-Bennur. South of the Haridra (the little river which has been dammed back to form the great Sulekerra tank), a considerable show of contemporaneous trap appears through the cotton soil spreads.

At Mallé-Bennur.

At Mallé-Bennur a remarkable bed of coarsely brecciated quartzite makes a great show, forming a conspicuous ridge which has been utilized to form great part of the bund of a small, but deep tank. South of the tank the breccia bed runs up into and forms the backbone of a much more important ridge. It becomes increasingly hæmatitic and less and less brecciated as followed southward. The dip of this bed is eastward.

Underlying this brecciated hæmatitic band is a considerable thickness of chloritic schists, in the upper part of which are many laminæ, and small nests of crystalline limestone. A very good show of gold was found on washing the sand of a small stream which flows into the tank from the western slope of the ridge just mentioned. The gold is probably derived from some of the many small blue quartz veins cutting the chlorite schist. No large reefs were visible. Underlying the schists is a bed of trap apparently of contemporaneous origin. To the west of the trap flow, but not seen in contact, is a quartzite so much altered by crushing and weathering that it has in parts assumed quite a gneissoid appearance. This is followed downwards

[1] The Honnali gold-field so called, which formed the western extremity of my traverse across Mysore in 1881,—lies along the south side of the Honnali gneiss inlier. The two principal mines that have been opened in it are those of Kudri Konda and Palvanhalli.

(stratigraphically) by a thick band of dark schist, chiefly argillitic, which in its turn is underlaid by a great thickness of pale green and grey schists of variable character, but chiefly chlorito-micaceous. Small beds of quartzite are intercalated here and there, and veins of white and pale bluish quartz are numerous but very irregular in size and shape. These beds form the main mass of the Hanuman-betta hill group.

The schist series here makes a great curve, the western part trending west and crossing the Tungabhadra some 15 miles to the westward, while the south-eastern part trends south, and may equally be followed by the eye for many miles, forming very considerable hills and ridges.

The Honnali Gneiss inlier.

On getting down to the low country at the south end of the ghat leading to Honnali, an inlier of granite gneiss is reached which occupies the greater part of the valley of the Tungabadra, between the town and the gold-field known as the Honnali gold-field. The western extension of the beds which cross the Tungabhadra north of Honnali town forms a band of hills of considerable importance which can be seen to stretch away north-westward for a great distance.

The south-west side of the inlier is bounded by a great fault by which the gneissic rocks have been brought up and exposed over a large area by the erosion of the Dharwar beds which formerly covered them. The fault extends along the whole south-western side of the inlier and crosses the Tungabhadra. I did not follow the fault across the river. The eastern boundary of the inlier, like the northern one, is a true erosion boundary.

Honnali gold-field.

The belt of country on the south-west side of the inlier which constitutes the Honnali gold-field was carefully examined by me in 1881, and in part re-examined last year. The northern part of the belt is occupied by a great thickness of chloritic schists, underlaid to the south by a great mass of quartzites and conglomerates with some argillites. These, from their superior hardness, have been much less denuded than the chloritic beds and form, especially in the north-west part of the belt, hilly ridges of considerable height. The Honnali gold-field is divided by the Nyamti nullah into divisions of pretty equal length and breadth, which may be conveniently called the Kudrikonda and Palvanhalli divisions, after the two important gold mines which have been already opened on them, the former to the west, the latter to the east, of the Nyamti nullah.

In the Kudrikonda, or western division, chloritic schists only show in the plains, but in the eastern division, east of Palvanhalli mine, numerous intercalated quartzites, quartzite sandstones, and gritty beds appear, and rise into good-sized hills as they are followed eastward. The great contortion these beds have undergone has caused considerable local metamorphism, and the true detrital character of the gritty beds is in many places not apparent; where, however, they are coarse in texture, and approach in character to pebbly beds, their true origin can be recognized at once. This is the case also with regard to the great beds of conglomerate and flaggy quartzite in the lofty Kalwa-Rangan-betta ridge which forms the south side of the Kudrikonda division of the gold-field.

The Saulonga inlier.

To the south of the Kalwa-Rangan-betta ridge, lies another inlier of gneiss of considerably smaller area than the Honnali inlier just referred to. It appears to owe its origin to an important fault

running north-west along its southern boundary, and somewhat parallel with the great fault which forms the south-west side of the Honnali inlier. Owing to the thickness of the soil and extensive jungle, the gneissic rocks are but little seen at the eastern end of this inlier where crossed at Saulonga by the high road from Honnali to Kumsi. Near the centre of the inlier however, some small rocky hills of granite gneiss show up sufficiently to be recognized from the top of Kalwa-Rangan-betta. Any one not having seen these might easily cross the inlier at Saulonga without becoming aware of its existence.

The Dharwar rocks are very little exposed in the Kumsi hills which lie south of this Saulonga gneiss inlier, owing to the dense forest covering them, but the shape of the hills clearly indicates the continuance westward of the beds which form the hilly tract along the northern side of the Shimoga gneiss inlier, the largest of the whole group of four forming such a striking geological feature in the north-western corner of the Mysore territory. At the north-western end of the inlier, some of the beds, which in the Kumsi hills have an east-to-west strike, trend south-westward and form the great ridges forming the Shankar-gudda and Kormur-gudda hills, which may be seen to extend for many miles southward. Another part of these beds trends north-west in the direction of Sorab, but they have not been followed beyond a point a little to the north-east of Anantapur.

The Shimoga inlier.

South of the Saulonga inlier lies a very much larger one, in the centre of which stands the town of Shimoga, the south-western boundary of which is also formed by one or more faults running north-west to south-east, which are very apparent even on cursory examination, but the extremities of the fault line are obscure, owing to the extensive jungle prevailing to the south of Kumsi and north-west of Tarikere. To the south of the inlier occurs the promising auriferous locality known as Honnahatti, where some noteworthy old workings were found by me in chloritic schists traversed by well-marked quartz reefs. The chloritic schists strike north-west to south-east with a steep dip to the north-east. The Honnahatti workings stand on the narrow strip of the Dharwar rocks, which separates the Shimoga inlier from the Tarikere inlier, the last and most southerly of the group of four. Washings in the small stream draining the south side of Honnahatti gave very fine shows of gold.[1]

[1] NOTE.—A special feature demanding notice in the western half of the Shimoga inlier, and still more striking over the gneissic tract of the Dharwars near Anantapur is the development of lateritic rock which covers the surface almost ubiquitously and to considerable depth, rendering it extremely difficult to find any outcrop of the underlying older rock. I have not attempted to show the laterite on my map separately from the gneiss on which it mainly lies, as my brief visit to this north-west corner of Mysore did not afford me time to determine the relationship between the rocks. I did not see enough of the laterite to feel satisfied as to its being of true detrital origin or merely a product of weathering, as is much of the laterite on the southern parts of the Deccan trap described in my South Mahratta Report (Memoirs, Geological Survey of India, Vol. XII, 1876). The laterite which I am (so far as my observation goes up to the present) inclined to regard as formed by weather action, constitutes a nearly uniform cover to the whole country, whether it be flat or hilly, with a generally pale, reddish, more or less clayey surface, which affords but little nourishment to vegetation. The grasses, especially seem to thrive very badly and are very coarse in quality, a chief reason probably why cattle and sheep succeed so badly in the Malanad, as the forest clad, western portion of Mysore is locally designated by the natives.

The Tarikere gneiss inlier.

The existence of a great fault along the south-western boundary of the Tarikere gneiss inlier has not been proved, but I have no doubt it will be shown to exist whenever the country may be geologically surveyed. The rocks are very little exposed either in the area of the inlier or in the ridges of Dharwar age which surround it. Extensive jungle and great spreads of soil effectually hide the rocks in most places east of the Tarikere inlier; a change takes place in the nature of the country, the great jungles are met with no longer, and the slopes of the hills being exposed to unchecked denudation, show an abundance of outcrops of all kinds.

Kaldrug Conglomerates.

Along the south side of valley running eastward of Tarikere are numerous outcrops of quartzite with schists, and near the eastern end of the valley appear great outcrops of an extraordinary conglomerate of extreme coarseness. The pebbles, often approaching in size to small boulders, consist of granite or compact granite gneiss cemented together in a foliated chloritic matrix. The beds culminate in a considerable hill, called the Kaldrug in the Indian Atlas (sheet 57), which presents a most rugged appearance. The beds east of the conglomerate are largely quartzites which form a high ridge with a great cliffy scarp on the eastern face of "Coancancul" peak (Atlas sheet No. 60). East of these, again, comes a great thickness of pale chloritic schists. These schists extend north of the Tarikere valley, and form the hills north-west of Ajimpur, and extending up to and beyond Chiranhalli, where washings in the small streams cutting across them yielded very satisfactory indications of gold. The conglomerate beds appear also to be represented on the north side of the Tarikere valley, for a long line of excessively rugged outcrops shows to the west of the schistose band in a strictly corresponding position. The Chiranhalli pale chlorites are largely mixed with pale talcose schists, both of which rocks contain very numerous crystals, mostly small, of cubical iron pyrites, and further numerous octahedra of magnetic iron. These latter are locally distributed.

Santaveri Section.

To return to the west end of the Tarikere valley, a large development of chloritic schists occurs extending southward for a considerable distance. South of these, and underlying (?) them, come great thickness of trap flows, which form great part of the great Santaveri spur, joining the lofty Dodda Bala Sidderu mountain (5,136 feet high) with the yet higher mass of the Bababuden mountains, which here attain an elevation of 6,155′ in the Kalhattigiri peak. The trapflows are disposed in a very flat anticlinal curve, and to the west are seen to be overlaid by a great thickness of dark schists (? argillites) with hæmatitic bands and quartzites overlying them again. These schistose beds are splendidly exposed in the great scarp which runs all along the eastern side of the Bababuden mountains from north of Kalhattigiri to south-west of Mallaingiri, the most southerly peak of the mass (6,317′) and the highest point in Mysore State.

Basement beds near Chik Magalur and Sigegudda.

To the south of Chik Magalur, and again to the south-west of the Sigegudda mountain, north-west of Hassan, the basement bed of the Dharwar system is formed by pebbly quartzites dipping north- and north-east respectively. The latter beds are seen to extend southward along the western side of the narrowing band of Dharwars described above (page 45) as running north-westward of Hassan. Quartzites overlaid by

schists form the narrow band of Dharwars which runs south from near Harnhalli close to Narsapur, and constitutes the southern extremity as far as yet known of the Dharwar-Shimoga band.

II.—*The Dambal—Chiknayakkanhalli Band.*

As in the case of the Dharwar-Shimoga band, the northern extremity of this tract of Dharwar rocks is very badly seen, owing to the vast waste spreads of cotton soil which cover the great plain forming the eastern half of the Dharwar District. The only exposures of any importance of the Dharwar rocks in this part, are beds of schist and hæmatite in the scarps of the Nargund and Chick Nargund hills below the cappings of quartzite of the Kaladgi series (Kadapas) which form the summit plateaus on both hills and rest on the Dharwar beds in the most marked unconformity. The Dharwar beds are upturned at high angles and dip 50°—70° east by north in the Nargund hill, the quartzite capping of which, a finely scarped plateau, is approximately horizontal. At Chick Nargund the quartzite capping has a dip northward, while the schist beds on which it rests have a strong dip to east by north.

Sections at Nargund and Chick Nargund.

Nearly equidistant from the two Nargund hills to the westward, a patch of contemporaneous trap rises above the cotton soil surface and forms a blocky ridge about 3 miles long by half to three-quarters of a mile wide. The rock is a diorite (?) of dark greenish colour.

Asmatti Trap-flow.

I did not follow the band up from Nargund, but marched south-west to Naulgund where there is a hill capped by a singular inclined plateau of a rock which may be a quartzite, very highly metamorphosed, but may also represent a run of the brecciated quartz which occurs so commonly in the granite gneiss area, adjoining and throughout the granitoid areas of the Ceded Districts. The plateau inclines to the north at an angle of about 45° which is a lower dip by far than observed elsewhere in any quartz run of unquestioned character,—still on the petrographic evidence of the rock itself it appears rather to be such a quartz run, greatly depressed by some local faulting, or other, than an altered quartzite of the Dharwar system. No exposure of the Dharwars was observed by me in the bed of the Bennihalla, the large stream which after draining this region, falls into the Malprabbha near Badami town. Whether any outcrops of the rocks occur between the Bennihalla and the northern extremity of the Dambal hills near Gadag (Gudduck) is uncertain; but there is every reason to suppose that a strong band of them exists under the cotton-soil spread, for a great thickness of chloritic schists rises out of the plain already a little to the north of the high road leading from Gadag (Gudduck) to Hubli. South of the road two great bands of hæmatite schist stand out conspicuously among the other softer schistose rocks, and may be followed continuously for ten or twelve miles south-eastward.

Naulgund hill.

Chloritic schists near Gadag.

Further south, another apparently underlying hæmatite band with associated chloritic, hornblendic, micaceous schists and crystalline limestones forms an anticlinal arch and is overlaid to the westward by another hæmatitic band, and this again by two

The Dambal gold-field.

others with associated argillites of reddish-buff or mottled whitish colours. These are greatly affected by cleavage, which completely obscures the bedding in many places, and renders their stratigraphical relations to the rocks next succeeding to the westward very problematic. This next series consists of chloritic and hornblendic beds intimately associated with a massive dioritic (?) rock, probably a contemporaneous trap, which covers a belt of country some 4 or 5 miles wide, and abuts to the westward against the granite gneiss which here forms a broad band extending westwards till it is overlaid by the eastern edge of the Dharwar-Shimoga band near Luxmaishwar, as described by Newbold.[1] The two most westerly beds of the hæmatite series form the mass of the Kappatgode, the centre and highest point of the plexus of hills which occupies the southern part of the gold-field.[2]

Surtur trap flow.

The auriferous nature of the rocks of the Dambal gold-field has long been known, and the surface of several of the quartz reefs been broken up by native miners at some former period. Gold washing is still followed by a few "Jalagars," professional gold washers, particularly in the larger streams rising on the area occupied by the contemporaneous trap above mentioned. The two largest nullahs, known respectively as the Surtur and Dhoni nullahs, from the principal villages near which they flow, are the richest in gold sand. The quantity of gold obtained is small, too small indeed to tempt many to engage in washing for it. Quartz reefs occur in all parts of the gold-field, but those found in the western part among the chloritic and argillaceous schists adjoining the trap area, are the best defined, and have received most attention from the old miners. They are doubtless the principal source of the gold obtained there. The only reef from which I obtained free gold was one of this set. It lies on the eastern slope of a ridge about 8 miles due west of Dambal, and has a north by west, south by east course, with a hade of from 40° to 50° east, and is about half a mile long.

The auriferous reefs.

Hattikatti reef.

A few small excavations hardly worthy of the name of pits had been sunk along the eastern side of the reef at some time prior to my visit, but I could not obtain any satisfactory information as to whom they had been sunk by. As already mentioned, I obtained no gold from any of the other reefs, and the indications of gold from washings in the streams draining the sites of the other groups of reefs to the eastward of the Kappatgode hill were far from encouraging.

The quartz of the Hattikatti reef from which I got the specimen of free gold, and of the majority of the reefs throughout was of the ordinary kind, white or milky in colour, but very largely iron-stained in parts. The group of reefs occurring south of the village of Dhoni on the east side of the Kappatgode[3] differs from all the others in consisting of distinctly bluish, or deep grey, diaphanous quartz, with a few enclosed scales of white or pale mica.

The Dhoni groups of reefs.

[1] In his paper on the Geology of the South Mahratta Country, and elsewhere.

[2] A more detailed account of the rocks forming the Dambal will be found in Part 4, Vol. VII of the Records, Geological Survey of India, 1874, in my paper on the Auriferous Rocks of the Dambal Hills, Dharwar District.

[3] Shown in the map accompanying my paper referred to above.

The reefs, excepting that of Hattikatti, and two others a little distance to the S. W., showed no sulphides of any kind, and those three yielded only a very few cubical crystals of iron pyrites. The argillites and chloritic schists, however, show great quantities of cubical crystals of that mineral converted into limonite by pseudomorphism.

The different members of the Dharwar system occurring in the Dambal area are seen to extend far south in the band of hills stretching away down to the valley of the Tungabhadra, which they cross and re-appear on the south side in the Haddagalli taluq of the Bellary District. The intermediate part of the band has not yet been examined, but being very bare of vegetation it is very easy to see the disposition of the outer beds on either side from a moderate distance. To the east of the band, the beds there, as further north near Gadag, are faulted against the granite gneiss, the downthrow being on the west side of the fault. The fault crosses the Tungabhadra and runs on for some 4 miles, when it is crossed or joined by another fault, running nearly east-north-east to west-south-west, and is no longer traceable to the southward.

The Tungabhadra gorge section.

To the west of Dambal town the band of Dharwar rocks is fully 13 miles wide, but it narrows greatly as it approaches the Tungabhadra, being a little less than 5 miles across in the gorge of the river. The section here seen shows, when followed from east to west, the following series:—

10 Hornblendic schists.
9 Hornblendic trappoid.
8 Contemporaneous trap.
7 Trappoid.
6 Flaggy hæmatitic quartzite.
5 Boulder conglomerate.
4 Contemporaneous trap.
3 Schists and argillites.
2 Hæmatitic schists.
1 Hornblendic Trappoid.

Of these the conglomerate is the most noteworthy because of its extreme coarseness, many of the boulders included being more than 1½ foot in diameter. The conglomerate is very little altered, apparently, and boulders which have weathered out are perfectly smooth and water-worn. None were seen showing any striations on groovings.

Continuance of the band into Mysore.

The hornblendic schists seen at the eastern end of the gorge section extend southward, and appear to form the backbone of the high ridge forming the bold Bettada Mallapah Gudda. The extension of the beds forming this ridge may be clearly traced by the eye for a long distance south-east. The ridge sinks down as it approaches the valley of the Chinna Haggari, south-east of which detached hills of schistose rock indicate the continuance of the Dharwar band up to and across the Mysore frontier. Another ridge of hills rises here and connects the Dharwars of Harpanhalli taluq with those around Jagulur.

Honnamaradi gold-field.

A few miles south of Jagulur occurs another auriferous tract that yielded highly promising quantities of gold on washing the sands of two streams rising on the west and east sides respectively of the little hill lying north of Honnamaradi. The hill consists of

drab or yellowish gritty schist passing into argillite in parts, on the south-western side of which several medium sized reefs of quartz appear running nearly north and south. Immediately east of the Honnamaradi (golden hill), the gneissic rocks are seen with an apparently faulted boundary in between. On the bank of a small nullah which flows south, a couple of hundred yards to the east of the hills are the remains of some large dumps where the old jalagars had evidently washed the sands for a considerable time. A washing of "dirt" from the bed of the nullah gave a handsome show of gold, of good grain and excellent colour; while a washing from the little rivulet flowing from the western side yielded a rich show of very coarse gold of the highest quality.

No gold was seen *in situ*, but there is every reason to believe it came from the reefs above referred to, as the streams in which the washings were made, especially the western one, have such very short courses that they could not have brought their gold-supply from any great distance. West of the schist beds forming the Honnamaradi hill and the tract westward of it, appears an underlying bed of jaspideous quartzite which has been tremendously brecciated by some obscure cause. The rock weathers of a very dirty dark colour, nearly black in many places, and is often very obscure in character and hard to determine. The breccia character becomes obvious only when the enclosed jaspideous pieces are paler than the matrix.

The Goeshwar hill trap flow.

West of, and underlying the brecciated quartzite is a great development of contemporaneous black trap (diorite ?) which extends southward a long way and forms great part of the mass of the fine Goeshwar hill, the loftiest hill in the band northward of Chitaldrug.

Kotemaradi gold-field.

Proceeding southward still, we come to the Kotemaradi auriferous tract, which consists of a great bed of chloritic schists overlaid by quartzites, and these again by a thick series of other schists, the lower beds being argillites. Traces of a contemporaneous trap show along the western basement of the Dharwars.

Quartz reefs are rare or else covered up by the extensive talus. The only one of any size seen was a good-looking one of bluish quartz running through chloritic schist at foot of the western slope of the southernmost of the three big hills which rise northward of the little Kotemaradi hill. The reef is just north of the stream draining the western slopes and close to some old workings of small extent.

Quartzites a possible source of gold.

The quartzites on the Kotemaradi are of no great thickness, and are locally much altered, nearly converted in many parts into true quartz, and generally permeated by large numbers of small quartz veins. It will be curious to ascertain, as doubtless there will ere long be opportunities of doing, whether this altered quartzite contains any gold. It is certain that the small stream draining the western and northern slope of the Kotemaradi carries down a notable quantity of large gold of excellent colour, and that no reefs of any size or importance show through the extensive talus covering the slopes.

Chitaldrug granite hill.

To the south of Kotemaradi, the Dharwars form a small bay opening to the west, at the southern side of which stands the old town

of Chitaldrug, with its grand old granite hill capped and surrounded by a noble fort or Drug, formerly one of the centres of the Bidars, one of the bravest and most independent of the Hindu tribes in the Deccan.

Jogamaradi trap flow.

Belligudda copper mines.

To the south of Chitaldrug the basement bed of the Dharwars is a great contemporaneous trap of great thickness and extent which forms the summit of the Jogamaradi, one of the highest mountains in this part of Mysore. Overlying this great trap formation is a great thickness of schists, some of which form the Belligudda (hill) noteworthy as having contained some considerable pockets of copper ore, which were exhausted by miners of whom no record appears to exist. The ore mined was, as far as can be judged from the refuse heaps, an earthy malachite, or carbonate of copper. No signs of a lode can be seen running through the clay-schist forming the Belligudda. The axis of the hill is a hard bed of jaspideous hæmatite quartzite which stands nearly vertical.

Halekalgudda side band.

To the south of the Jogamaradi mountain, south of Chitaldrug, the width of the great band is nearly doubled by the junction with it of a parallel band, which commencing somewhere to the south of Harpanhalli [1] forms the Halekalgudda and some other hills east of Maya Konda, and then sweeps into the main band. A little to the east of the junction, the Dharwar beds attain their greatest elevation in this part in a peak to which the Trigonometrical surveyors assign a height of 3,863′ above sea-level.

The geological structure of this side band, which may conveniently be called the Halekalgudda band, shows no special features so far as it was examined, unless it be a rather greater development than usual of gritty, locally conglomeratic quartzites. With these are associated siliceous, micaceous and chloritic schists. These are underlaid by a great flow of dioritic trap which in its turn is underlaid by a considerable thickness of schists. Some fine quartz reefs cross the footpath crossing the hill south-westward from Halekalgudda village, but none were seen near it, though a good show of gold was obtained by washing near the north end of the hills. Where the highroad from Chitaldrug to Holal Kere crosses the southern part of the Halekalgudda band the country is very flat and much obscured by thick red soil, but the connection of this band with the main one is made clear by the existence of a low ridge formed by an outcrop of a purely ferruginous bed of hæmatitic quartzite which rises rapidly, both to the north-west and south-east, and soon becomes an important object in the landscape.

The fine views to the south obtained from the tops of Belligudda and Jogamaradi show the Dharwar rocks extending far to the southward in great force towards the great gorge by which the Haggari river (locally known as the Varada) cuts through the hills of the Dambal-Chiknayakanhalli band, while from the south from the highest point east of Chiknayakanhalli town the beds are seen to range continuously northward to the same point. Though not traversed as yet by the geological surveyors, there is ample evidence as to the existence of the Dharwar rocks between the known tracts near Chitaldrug and Chiknayakanalli.

[1] The northern extremity of this side band has not yet been visited, so its exact position is not known. It extends about 50 miles in length.

The Chiknayakanhalli gold field.

At Chiknayakanhalli we come again upon an auriferous tract which is frequently spoken of as the Chiknayakanhalli gold-field. On Honnebagi hill, a couple of miles south-east of the town, old workings of no great size occur just within the boundary of the Dharwar area. The reefs occurring here are not promising in superficial appearance, being white and hungry-looking; but the quantity of gold obtained by washing in the small streams flowing down the hill is not by any means contemptible, and deeper prospecting might give still more favourable indications.

Dodrampur hill synclinal.

The basement bed is here a quartzite which is overlaid by a thick series of schists, hornblendic, chloritic and micaceous, occupying the space up to the foot of the hills, where they are overlaid by argillites and a great thickness of hæmatitic schists, locally very rich in iron. The weathering of the highly hæmatitic schists gives rise to the formation of subaerial breccias which assume a lateritoid appearance from the action of percolating rain water. The denudation of these rich, red argillites and hæmatites gives rise to the formation, further to the south, of an extensive talus of deep red soil.

The stratigraphical position of the main ridge east of Chiknayakanhalli appears to be an elevated synclinal, but the eastern side shows a succession of formations discordant from that on the west, and there may very probably be a fault running parallel with, but a little east of the axis of the synclinal.

Dodrampur limestones.

About half-way down the eastern flank are extensive and important formations of sub-crystalline limestone, mostly grey in colour, and with very numerous siliceous partings in the form of quartzite, which here and there attain to the magnitude of distinct beds. These limestones must be several hundred feet thick. East of the little fortified temple of Dodrampur they are underlaid by a great chloritic schist formation. The limestones cover a large area stretching away south-east from the main ridge, and a small show of them is to be seen on the west side of the main ridge, just opposite the mouth of the deep gorge east of Ballenhalli.

Kibbanhalli branch band.

To the south-west of Chiknayakanhalli lies a branch of the band which runs north-west some 14 or 15 miles from its point of divergence from the main band. Where crossed by the high road from Shimoga to Bangalore, it is seen to have a great flow of trap as its base, on which rest chloritic and other schists to a considerable thickness. To the south of the point of divergence just referred to, the whole band trends strongly eastward, and keeps on the left bank of the upper course of the Shimsha river. I was unable to follow it up east of the Shimsha, but I feel convinced that the Dharwars stretch away south-west by Kunigal, and then south, past Huliyurdroog and further south, narrowing greatly the while, across the Madras railway. The hills stretching away south of the Yadiyur-Kunigal road present the dark colour and smooth appearance so characteristic of the Dharwar rocks elsewhere, while the country round Huliyurdroog is well known to be auriferous, and the look of it from the railway near Mudgeri station on the Mysore State Railway assures me that it is so.

Kunigal-Huliyurdroog extension of the main band.

Extension southward into Coimbatur District.

On theoretical grounds I believe that a great band of Dharwars, by its geographical position an extension of the Dambal-Chiknayakanhalli-band, stretches south from the valley of the Cauvery, near the falls of Siva Samudram, across the Kollegal taluq, and down near to the valley of the Bhowani river, if not yet further south into the central part of Coimbatur District. That a second parallel band of the same rocks may exist further east near Kandali, I regard as more than probable. It will assuredly contain the extensive old workings known to exist in that immediate neighbourhood. I do not mark these bands in my map, as I have not been able to obtain sufficiently close views of them to lay down their actual positions.

The Kollegal bands.

The Shettihalli branch band.

To return to the Dambal-Chiknayakanhalli band, at its eastern bend in the upper valley of the Shimsha river; the main band, as far as width is concerned, appears to be the Kunigal band. The branch which diverges from it a few miles north of the Yadyur bridge over the Shimsha is a very narrow one to start with, but widens a little near Nagamangula only to contract again and remain a narrow tract, as far as traced, down southward of the Cauvery immediately east of the east end of Seringapatam island. I will designate this as the Shettihalli band.

Kalinganahalli gold washings.

A little south of the Yadyur bridge an auriferous tract is encountered close to the village of Kalinganahalli. Here good washings of gold are reported by Mr. Chas. Ogden, M. E., but no reefs of any size could be seen, merely small veins in great numbers traversing the country rock. Numerous dumps thickly scattered about show that the old miners had been busy here washing on a large scale.

The Dharwar rocks seen here are hæmatitic quartzites of no great thickness, but very distinctly marked, with overlying chloritic and hornblendic schists, which stretch down south till abreast of Nagamangala. Various good-looking quartz reefs occur in this tract.

Honnabetta outlier.

A mile and half south by west of Nagamangala town is Honnabetta hill, an outlier of the Dharwars, consisting, so far as examined, of hornblendic and chloritic schists, with at least one fine-looking reef at the northern end of the main hill. A good washing was obtained in the stream draining the north-east side of the hill. A mine is being opened at the extreme north end of the Honnabetta outlier on a reef running through chloritic schists, which is traversed closely by a pale green dioritic (?) trap. This is the Girigudda mine. I obtained a very fair result by washing in the little stream draining the east side of Girigudda hill. Chloritic schists form the mass of the small, but rather high spur which diverges from the Shettihalli band and crosses the Lokapavani river some 10 miles S. S. W. of Nagamangala.

Girigudda mine.

Further south, where the Mysore State Railway crosses the Shettihalli band, the Dharwars consist mainly of quartzites and horneblendic schists, and form a very unpromising region for mining, as far as surface indications go. The reefs seen are small, and the quartz is white and hungry-looking, and contains very few minerals. Those noted in it were blackish, greenish, mica, and a white decomposing felspar. The included minerals show but very rarely and at wide intervals, but here and there

become numerous and convert the reefs into true granite veins; rocks which are not as a rule rich in the precious metal.

Karigutta felspar porphyry.

The most southerly point to which the Shettihalli band has been examined is the Karigutta hill overlooking Seringapatam. The most striking feature here is a very fine large dyke of beautiful, reddish-brown felspathic porphyry, which might furnish an inexhaustible supply of a superb decorative stone fit for vases, panels, bases for busts, and tazzas.

The extension of the Shettihalli band southward of the Cauvery has not yet been followed up by me. But there can be no doubt that it does extend much further. I am not prepared, however, to support fully the idea which I fathered in the map accompanying my paper on the traverse across Mysore, that the Shettihalli band extended far to the south-west and joined the band of auriferous rocks forming the Wynaad gold-field, I have therefore indicated no such connection in the new map.

Notes on the Igneous rocks *of the districts of* Raipur and Balaghat, Central Provinces, *by* PRAMATHA NATH BOSE, B. Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a plate.)

The igneous rocks treated of in these notes occur in the jungle-clad border country forming the water-shed between the districts of Raipur and Balaghat, and situated north of Dongargarh, and west of Lohara, Gandai, and Khairagarh. They are, as a rule, unbedded; and they alternate with ridges of Chilpi shales and sandstones, which are probably of Transition age. Their general parallelism to the strike of the Chilpis is notable.[1]

Area; mode of occurrence.

Felsites.—These are almost exclusively confined to the eastern portion of the area, only a small patch having been encountered in the western portion, east of Bijagarh in the district of Balaghat. The ground occupied by the Felsites in the eastern area may be sub-divided into two portions—one lying to the north of Thakurtola, and the other to the south of that place. In both ot these areas, they run north-south parallel to the strike of the sedimentary Chilpi strata; and in both, the eastern and western boundaries are approximately straight.

South of Doomureea (a village 3 miles west of Lohara), as well as near Koylaree (west of Silheti), the felsites were seen to be in lateral contact with highly altered vitrified quartzites. A mile north of Doomureea, on a felsite-hill locally known as Dalhea, I came across huge blocks of a hard, laminated, quartzitic-looking rock, which looked as if they had been carried up entangled in the felsitic mass. Small patches of shales and quartzites with the Chilpi strike, and belonging apparently to the Chilpi series frequently occur in the midst of the felsites, especially in the

[1] For a general geological map of a portion of the area, *vide* Rec. G. S. I., Vol. XVIII, p. 169.

country west of Doomureea. They look like remnants of beds which have been forced through by the felsites. One such patch was well seen just west of Magarkund. It is surrounded on all sides by the felsitic rocks.

The absence of bedding, the straightness in direction of the felsitic outcrops, the alteration visible in the adjacent rocks at places, and the presence of included Chilpi fragments, as well as of patches of Chilpi rocks in the form of islets, suggest the intrusive origin of the felsites.[1]

Age.

East and south of Thakurtola, as well as west of Khairagarh, the felsites are overlaid with a certain degree of unconformity by sandstones and conglomerates, which form the base of the Chhattisgarh Plain Series, and to which the name of "Chandarpur sandstone" has been applied. Chandarpurs lying in hollows scooped out in the felsitic rocks is rather a common occurrence. We may hence infer, that the felsites are older than the Chandarpurs. The fact, that at places, as at Lumna (north of Thakurtola) and elsewhere, the basal conglomerates of the Chandarpur group contain rolled fragments of the felsites corroborates the inference. There are a few circumstances, however, which lead me to think, that the felsites cannot be much older than the Chandarpurs. It is even possible, that minor intrusions continued while the latter were being deposited. The vitrified quartzites west of Koylarce, and south of Doomureea, referred to above, have not been traced into indubitable Chilpis; and the occurrence of Chandarpurs in their neighbourhood raises the not unreasonable suspicion, that they may belong to that group. West and north-west of Thakurtola there are tuffs associated (to all appearance, interbedded) with the lower Chandarpurs; and these tuffs may have been formed of *ejecta* from felsitic dykes in the Chandarpur period. The felsites would thus appear to have been intruded through the Chilpis prior to, and possibly also, in part contemporaneously with, the deposition of the Chandarpurs.

Felsites intruded close to shore and parallel to coast line.

The small thickness and breccio-conglomeratic character of the Chandarpurs plainly declare them to be a shore deposit, and the Saletekri range (formed of Chilpi rocks) probably indicates the coast-line of the lake or inland sea in which they were deposited. The felsites would thus appear to have intruded as dykes close to shore, and parallel to the strike of the Chilpis, as well as to the ancient shore-line.

Petrography.

The typical form is a purplish rock much rent by fissures, and weathering to a brownish tint. The fracture is roughly conchoidal. Longish crystals of white felspar, and roundish ones of vitreous-looking quartz are macroscopically seen to be disseminated in it. The former are larger than the latter, some measuring as much as quarter of an inch in length. In the matrix, as well as in the crystals of felspar, a greenish decomposition product is often observed, sometimes to such an extent as to change the colour of the latter entirely to green.

[1] Intrusive felsites have been noted by Dr. King in the Kadapah formation (Chey-air beds), which is possibly of the same age as the Chilpis (Mem. VIII pp. 191, &c.). The remarkable parallelism of the felsites to the Chilpi outcrops, and the fact that they are seldom clearly seen to cross the strike, give them an appearance of being contemporaneous flows. But the presence of included fragments and of patches of Chilpi rocks is unfavourable to such a supposition.

Under the microscope, the groundmass is seen to be micro-felsitic. It is made up largely of minute slightly greenish, granules. Numbers of them are in some slides seen collected in interrupted, irregular, and more or less wavy lines. In a slice prepared from a specimen of a felsite which, though obtained from the southern portion of the district of Raipur, a little way to the south of the area under description, unquestionably belongs to the same series as the felsites we are treating of, microlites looking very like those in question are seen to be aggregated along the outer boundaries of the quartz and felspar crystals, appearing, as if, in flowing past these, they had met with some obstruction, and in consequence stuck together (H, Fig 1, Plate). These bundles of microlites are somewhat elongated and strongly dichroic in polarised light. There can be hardly any doubt, that they are microlites of hornblende. And it is not improbable, that a portion of the minute greenish granules of the felsite under description also belong to that mineral.

The larger quartz crystals have invariably a more or less rounded shape, and the edges are not very clearly defined. Fluid inclusions are abundant. Protrusions of the groundmass (G. Fig. 2) in the form of bays, and also along narrow cracks are common. Isolated patches of the groundmass are found in some, though rarely; and a few contain cubical crystals of oxide of iron. The smaller crystals of quartz, unlike the larger ones just noticed, usually exhibit more perfect crystal surfaces.

The crystals of felspar are invariably impellucid, being full of granular matter. They are usually rounded off at the corners, some appearing nearly elliptical in section. Their outline, like that of quartz crystals, is, in some cases, very ill-defined. As in the case of quartz, inclusions and intrusions of the groundmass are not uncommon. The characteristic twinning of orthoclase is exhibited by some in polarised light. No plagioclase has been observed. Cleavage lines are sometimes well seen as in fig. 1.

Some of the appearances noted above in connection with the crystals of felspar and quartz would seem to suggest, that they have not crystallised *in situ*. The seemingly isolated patches of the groundmass found enclosed in some crystals may, in reality, be connected by cracks with the groundmass outside, the connection being cut off in section. The frequent indistinctness of the crystal boundaries may be accounted for by partial fusion along the edges.

The greenish alteration product, patches of which are, in some cases, macroscopically seen in the matrix, as well as in the crystals of felspar is noticed, under the microscope, to be slightly dichroic with polarised light. Even where the product in question has invaded the entire felspar crystal, so as to appear macroscopically a pseudomorph of the latter, it is found, under the microscope, to be quite patchy, the unaltered portions of the felspar exhibiting various bright colours under crossed nicols.

At Khairbana and generally along the eastern margin of the felsitic area, there occurs a non-porphyritic purplish felsite associated with tuffs at places. The rock is much fissured and has a very uneven fracture. It is eminently liable to alteration, being sometimes almost wholly converted into quartz-rocks, as near Gubra, and sometimes into pseudobreccias. No bedding, however, is noticeable anywhere; and here and there unaltered portions of the matrix are met with.

A thin slice of a specimen from near Khairbana has a blotched appearance,

small brownish spots and patches being interspersed in a light purple matrix. Under the microscope, a few small bits of rather pellucid felspar are noticed, which appear to be fragments of much shivered larger crystals. They are partially rounded off at the corners; and the brownish substance noticed above invades them to some extent.

It is doubtful if the rock is a genuine felsite. It is probably a tuff, at least in part, belonging to the felsite series.

A dark coloured felsite occurs at Murghusri, Mohanpura, &c. On a fresh fracture, the felspar crystals are barely recognisable with the naked eye. But, on the weathered surface, which is light brown, somewhat as in the porphyritic variety, they are conspicuous by their white colour. Owing to the similarity of appearance at the weathered surface, the variety under consideration could not be distinguished from the porphyritic variety noticed above, without devoting to the rocks more time than I could command. The former possibly belongs to an intrusion different from that of the latter. Certain it is, that the black felsite differs from the purplish porphyritic form, not in colour only, but also mineralogically, in the extreme rarity of free quartz in it, and chemically, in containing proportionately less silica. The percentage of silica, as ascertained by analysis in the survey laboratory, in the porphyritic quartz-felsite is 73·47, but in the felsite under notice only 68·57. This last proportion just exceeds the maximum limit of silica (66 per cent.) present in intermediate igneous rocks.

Under the microscope, the groundmass is seen to be microfelsitic, as in the porphyritic form. The larger crystals of orthoclase are full of minute granules (the result probably of kaolinisation), and have their corners more or less rounded off.

Area, mode of occurrence.

Basaltic rocks.—These occur in the Chilpi area north of Dongargarh and, like the felsites, run parallel to the strike of the Chilpis. They cover the entire ground about Ghoteea, Bunnara, &c., forming an ill-defined range of scraggy hills. On the north side they abut laterally against a high ridge of sandstones sloping gently with the dip north-westward. The junction on this side is fairly straight; throughout it, however, the sandstones were nowhere clearly observed to have undergone any special alteration. The eastern junction, east of Ghoteea, is similar to the northern. Along the southern junction, however, the sedimentary Chilpis were found to be distinctly and highly altered. North of Koolharghat, and just south of Lingungarh, as also south of Ghoteea, there were met with along the junction, dark, bedded, igneous-looking rocks, resting on Chilpi sandstones with perfect conformity. They contain more or less rounded grains of quartz in abundance, and at places, look like gritstones or even conglomerates, with a trappean base. South-east of Ghukooree, there occur at the junction peculiar looking schistose rocks. Both these classes of rocks appeared to me to be the result of contact metamorphism.

West and north-west of Luchna, the basaltic rocks occupy a very large area extending to north of Bukkurkutta, where they are covered by laterite. Patches of shales, and more rarely of sandstones, belonging evidently to the Chilpi series, and similar to those occurring among the felsites, were encountered in the basaltic area.

An alternation of basaltic rocks, which appeared like minor dykes, and quasi-schists was met with on the Kaman pass (one of the passes between the districts of Raipur and Balaghat).

North of Mahuadhar and just south-west of Nemao Tola, there is a ridge of the basaltic rocks, in which blocks and boulders of quartzites of all shapes and sizes, some measuring no less than 20 feet in length, were encountered.

At places, as just west of Sitapala, the Chilpi shales in contact with the igneous rocks were found to be altered into hard thick claystones. Elsewhere, as west of Kurela (Karol on map), a peculiar-looking schistose grit somewhat like the rock mentioned above as occurring south-east of Ghukooree, was met with as contact rock. Frequently, however, the shales and sandstones in contact were found to have undergone no special alteration.

Relative age.

The facts noted above with regard to the mode of occurrence of the basaltic rocks appear to indicate that they are of intrusive origin. The fact that they follow the strike of the Chilpis very closely may suggest, as in the case of the felsites, that they are contemporaneous flows. But, as in the case of the felsites, the presence of patches of Chilpi shales and sandstones in the midst of the basalts cannot on this view be satisfactorily accounted for. The mode of occurrence of the basaltic rocks in the vicinity of Ghoteea and Bunnara, however, gives rise to the suspicion, that they belong to a flow contemporaneous with the Chilpis. For the latter are remarkably altered south of Ghoteea, at the southern junction. But no such alteration was noticeable at the northern junction, *i.e.*, the junction with the higher beds of the series. This junction, however, was much covered by *debris* from the sandstone hills, and was, altogether very obscure. I would not, therefore, lay much stress on this negative fact, *viz.*, the absence of alteration; and the basaltic rocks of the neighbourhood of Ghoteea, like their fellows occurring further north, have in all probability, an intrusive origin; are, in fact, intrusive sheets. There is, however, considerable uncertainty about their age. There is a minor intrusion of them in the felsitic area at Magarkund, and another a little way south, at a place called Bagdoor. An intrusion of the rock was also met with north of Magarkund in the country west of Lohara about Katangi-Mohanpura. The manner in which these intrusions occur left the impression in my mind that they are more recent than the felsites and felsitic tuffs by which they are surrounded. I have got no data which would fix their age with greater precision. Unlike the felsites, they are nowhere superposed by the Chandarpur sandstones, or, indeed, by any other sedimentary rock, except by laterite on the Saletekri plateau.

Lithologically, the rocks under treatment differ in a very marked manner from the felsites, but resemble the Deccan and Malwa trap basalts, though not closely; and for all that was seen in the field, they might be of the same age as the latter.

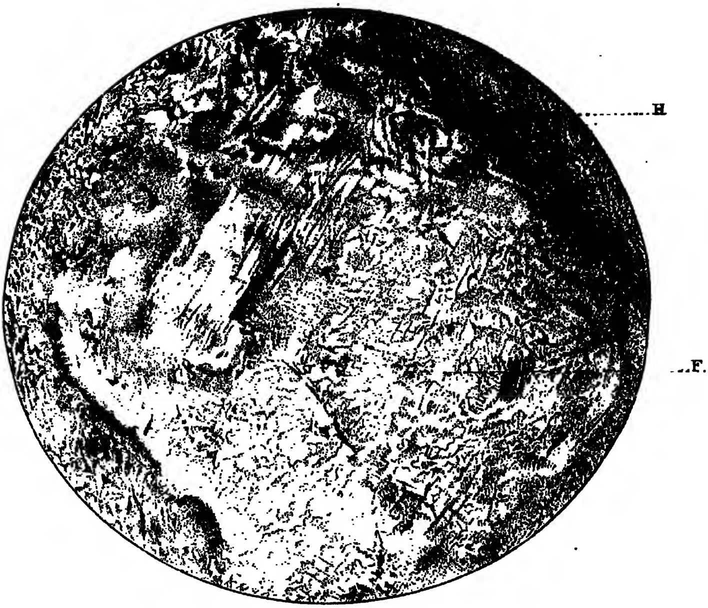
Percentage of silica.

By analysis of a specimen, in the laboratory of the Geological Survey, it has been ascertained, that the rock contains 49·57 per cent. of silica.

Petrography.

The basaltic rocks are hard, black, and compact. Macroscopically, black rod-like, minute crystals are visible in some. Under the microscope, these crystals are seen to be of a greenesh tint, slightly

Fig: 1.



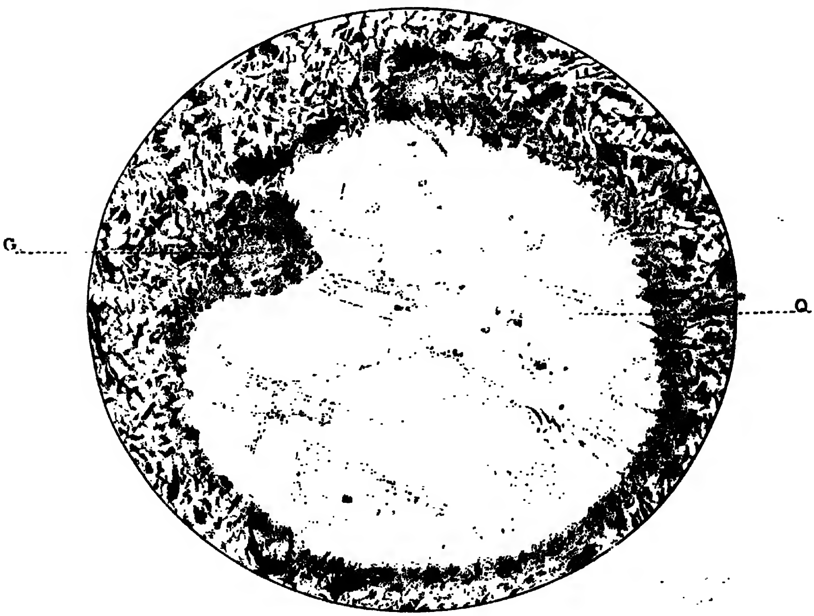


Fig. 2

but distinctly dichroic. They are as a rule irregular shaped; but a few eight-sided sections have been noticed. The mineral is, in all likelihood, augite. The ground-mass is crypto- to micro-crystalline. Minute, rod-like, whitish crystallites, probably of felspar, are present, as also greenish microlites. Large felspar is rare; when present it is ill developed, and barely distinguishable as plagioclastic. Magnetite occurs, but not in such abundance as in the Deccan and Malwa trap basalts.

In mineral and chemical composition, the rock presents close analogy with basalts.

Tuffs, volcanic agglomerates.—The association of tuffs with the Lower Chandarpurs west of Thakurtola has been already alluded to.[1] The most characteristic variety is a gritstone-like rock, very hard and massive-bedded, and weathering in huge, roughly spheroidal masses. Their matrix varies in colour from nearly black to very light pink, presenting various intermediate tints. The black forms are the most volcanic-looking, and the light the most sedimentary-looking. In fact, the last named varieties pass almost insensibly into ordinary whitish gritstones, as at Manpur and Lumna. Macroscopically, the gritstone is seen to contain large quantities of felspar and quartz in about equal proportion. The felspar varies in colour from white to flesh-coloured, and is, in the average, of about the same size as the orthoclase of the felsites. The quartz, however, is much larger than that of the last-named rocks.

Under the microscope, the matrix, which appears nearly homogeneous to the unassisted eye, is seen to be full of little bits of felspar and quartz. There is some interstitial matter, which is somewhat like the groundmass of the felsites. The felspar is found to be of the same species as in the felsites; some of the crys-stals bear evidence of abrasion at the edges. The quartz crystals have a most irregular outline, and like the felspar, have undergone some amount of attrition.

That the gritstone-like tuffs are water-laid, there can be hardly any doubt. They are, in all likelihood, formed partly of volcanic ejecta, and partly of sedimentary material.

The possibility of the non-porphyritic purplish felsites in the neighbourhood of Khairbana being, at least partly tuffs has already been adverted to. The fine-grained tuffs vary considerably in colour from purplish to black. Some are smooth and homogeneous with conchoidal fracture; others rough, with rather coarse and uneven fracture. The tuffs not unoften pass almost imperceptibly into well recognisable, clearly bedded sedimentary strata, as north-west of Bagdoor, north of the road leading from Gandai to Thakurtola.

EXPLANATION OF PLATE.

Figs. 1 and 2. Porphyritic Quartz-Felsite, south of Khuji, Raipur district.
,, F. felspar.
,, Q. quartz.
,, H. bundles of horneblende microlites.
,, G. Groundmass.

[1] *Vide* page 56.

Report on the Sangar Marg *and* Mehowgala Coal-fields, Kashmir, *by* TOM D. LATOUCHE, B.A., *Geological Survey of India.* (With one plate.)

Two areas in which coal-bearing rocks (which, for the purposes of this report, may be called "coal measures," though this term must not be taken to imply any connection with the true coal measures of Europe) are found, were examined by me,—the one occurring on the western and northern flanks of Sangar Marg hill, and the other in the valley of the Neari Tawi river, a tributary of the Bari Tawi, about 8 miles to the west of Kotla, surrounding the village of Mehowgala. These may be called the Sangar Marg and Mehowgala coal-fields respectively, and I shall describe them separately. The coal measures are probably continuous between these two areas, though separated at the surface by a broad band of newer rocks; but in most places are at too great a depth to be reached by mining. I spent only a few days in the examination of the Mehowgala field; but as the rocks met with are practically the same as those at Sangar Marg, and as they are much less disturbed by folding, I was able to form an opinion on their extent and condition more rapidly than in the case of the latter field.

I.—THE SANGAR MARG FIELD.

Geology.—The following is a vertical section of the rocks exposed in the field, such as would be found in a boring or well, sunk vertically through the strata where horizontal. It should be remembered that where the strata are inclined, as they almost invariably are in this field, the thickness of each bed passed through by a vertical boring would be greater than that here shown, in proportion to the angle of dip; also, the thickness of the different beds may not be exactly the same over the whole area, though that of the whole group appears to be very constant. For instance, I found the thickness of the band of carbonaceous shale immediately overlying the coal seam to vary from 3 to 10 feet within a short distance, and the thickness of the seam itself is also variable. The amount of overlying Murree Sandstone passed through would, of course, depend on the position of the boring if commenced in that rock. Its total thickness is unknown, but must be several thousand feet. That of the Great Limestone, too, at the base of the series is unknown, its base being nowhere exposed:—

Formation.		Description.	Thickness, feet.
Murree Group		Grey and reddish-grey sandstones, with beds of shale, weathering purplish-red	Undetermined.
Subathu Group (coal measures)		Nummulitic limestone, upper band, hard blue limestone, with large nummulites	4
	Upper shales.	Olive shales, with occasional thin nodular calcareous bands, sometimes containing small nummulites passing down into	200
		Finely laminated olive shales	
		Nummulitic limestone, lower band	

Formation.		Description.	Thickness, feet.
Subathu Group (coal measures)—*contd.*		Earthy limestone, crowded with small nummulites	20
	Middle Shales.	Shales, sandy near top, passing down into carbonaceous shales at base . . .	125
		Thin band hard sandstone, with pyrites . .	3
		Carbonaceous shales	3 to 10
		Coal .	2 to 5
	Lower Shales.	Finely laminated olive shales, carbonaceous near top	70
		Indurated pisolitic clay	5
		Brecciated conglomerate with iron ore .	Variable.
Supra Kuling Series.		Great limestone	Unknown.

It will be seen that the greater part of the coal measures consists of shales, with a few subordinate beds of harder rock, and that the coal seam occurs in the lower part of the formation, the shales on either side of it being carbonaceous. There is in this field only this one seam of coal, which is always found at or about the same horizon in the shales; the lower band of nummulitic limestone is a very useful guide to the position of the seam in any outcrop of the coal measures; as, being a hard rock, it weathers out more or less conspicuously from the surrounding shales, and the coal will always be found, if at all, at a certain distance beneath it.

In order to describe the distribution of these rocks in the coal-field, it will be convenient to take the lowest formation exposed, *viz.*, the *great limestone* (so named by Mr. Medlicott), as the higher rocks are everywhere conformable to the folds into which it has been thrown, except where the boundary between them is a faulted one.

This rock forms the main mass of Sangar Marg hill, where it is thrown into the form of a broad anticlinal curve or arch, with its axis running approximately east and west. This anticlinal is flanked on either side by two synclinal curves or troughs, occupying the valleys near the head of which the villages of Bugoola and Sujanpur are respectively situated. I shall accordingly speak of them as the Bugoola and Sujanpur synclinals. On either side of these again, the *great limestone* is bent up in narrow anticlinal folds, forming, on the south, the precipitous ridge to the north of Berh, and on the north a similar ridge along the northern side of the Sujanpur valley. In its easterly continuation along the line of the Puddar valley, this fold is faulted parallel to its axis.

The axes of all these curves are elevated towards the east, so that the anticlinals disappear gradually in a westerly direction. At the same time the synclinals between them broaden out. Thus the narrow ridge of *great limestone*, north of Berh, disappears near the village of Kroli on the path from Berh to Kotla; the *great limestone* forming the main or Sangar Marg anticlinal, disappears about 1½ miles west of the tank at Chakur; and that forming the ridge north of Sujanpur, near the lower end of the Sujanpur valley. Similarly, the depressions caused by the synclinals grow shallower, and tend to disappear in an easterly direction.

To the south of this system of folds, the rocks are much disturbed and faulted, and even inverted in places, so that the *Murree sandstones* are sometimes in contact with the *great limestone*, or appear to dip beneath it, as may be seen along the path leading from Berh near the village of Kroli; while the coal measures are either faulted out of sight, or so broken up as to be valueless. To the north, *Murree sandstones* apparently extend to the foot of the Punjab range.

Owing to the combined effect of the folds into which the rocks have been thrown, and the denudation to which they have been subjected, the coal measures appear at the surface as a continuous narrow band, running in an irregular direction between the *great limestone* and *Murree sandstones*. The area occupied by the *Murree sandstones* may be readily distinguished from that of the *great limestone* by the purplish-red colour of the soil formed by the weathering of the former, and the more rugged character of the hills formed by the latter.

Distribution of the Coal measures.—It is difficult to convey an accurate idea of the distribution of the coal measures without a large scale map; but I have prepared a section taken across the western portion of the field in a direction transverse to the strike of the rocks, which will be of some assistance in distinguishing the various folds I have described above. The section is attached to this report.

a. The Bugoola synclinal.

Entering the Kotla valley by the path from Berh, coal is first met with on the top of the low pass or *col* near the village of Kroli (or Kroo', which is somewhat to the east of its position as marked on the map).

The seam where first seen is a good deal disturbed, but seems to be from 4 to 5 feet thick; a short distance to the west, however, it is reduced to 2 feet 9 inches. The dip is apparently towards the *great limestone*, but within a few feet to the south, the dip of the overlying rocks is about 67° to S. W., or away from the *great limestone*. To the south-east of this point, the coal measures occupy a small valley at the foot of the *great limestone* ridge north of Berh, and are cut off to the south by a fault.

On the descent from the pass above mentioned to the Kotla valley, the coal measures follow the path for about ¼ mile to a patch of terraced fields; here they bend sharply to the east round the western end of the narrow ridge of *great limestone*, and enter the Bugoola valley. Along the southern side of the valley, they are deeply eroded, and generally concealed by cultivation and debris from the limestone ridges, but coal is exposed in more than one place; the dip is high to north. Near the upper end of the valley, at the place called Kala Mitti by the natives, the band of coal measures bends again sharply to the west along the northern slope of the valley. At the bend, denudation of the shales containing the seam has exposed it in such a manner as to make it appear that there is more coal here than else-

where; hence the distinctive name given to this spot. That there is, however, a considerable thickness of coal here, I found by a cut made across the beds where they were not denuded, and by a pit sunk some 300 yards to the west, along the southern outcrop. In the former place, the seam was 3 feet 6 inches thick, and in the pit 7 feet 6 inches. This pit afforded a striking instance of the manner in which the seam may be concealed by surface soil. At the surface, only a few inches of coal were visible, and that only where the grass had been worn away by a foot-path, and yet not 10 feet below there was this thick seam of coal.

Along the northern side of the valley, the coal meaures, dipping steeply to the south, are again eroded as far as the village of Kori, where a ridge of *Murree sandstone,* jutting out from the southern flank of Sangar Marg hill, has escaped denudation and protected them. Coal is again exposed on the *col* at the top of this ridge, between Kori and Ransu on the left bank of the Tawi, and again to the west at the lower end of the ravine near Ransu, just above the fields belonging to the village. On the *col,* the seam is 4 or 5 feet thick, and in the ravine about 3 feet.

The centre of the valley is everywhere occupied by rocks higher in the series than the coal seam; that is, by the upper beds of the coal measures towards the head of the valley, and by *Murree sandstones* lower down; so that the coal might be reached either by vertical mines on the floor of the valley, or by horizontal adits driven at points low down on its sides. In the middle of the valley, however, these upper rocks are nearly vertical, and it is impossible to say at what depth the coal seam would be reached. This could only be determined by boring. I do not think that for a mile at least down the valley from Kala Mitti, this depth would be found too great for mining on English methods; though in the lower portion of the valley a considerable water discharge would have to be contended with. Working from the outcrop should in no case be permitted in such highly inclined seams, as such openings would greatly facilitate the passage of water into the seam.

On the banks of the Tawi stream, near Ransu, the coal measures are entirely concealed by cultivation; and, where they cross the river, by its deposits of gravel and boulders. To the west of the stream they appear again in the ravine along which runs the path to Chakar, and coal is exposed on the path itself in more than one place as far as the *col* where the path from Brehal to Chakar is met. On the *col,* the coal seam is 2 feet 6 inches thick, dipping to S. 15° W. at about 20.° Down the ravine towards Brehal, the thickness of the seam increases, but at the same time the dip becomes much higher, until at Brehal it is nearly vertical. Here the seam is from 4 to 5 feet thick, but the shales in which it occurs are much contorted on a small scale, and the coal is crushed to powder. To the south, however, the dip of the rocks overlying the coal decreases, though still very high, about 70° in a southerly direction; and the coal would probably be found improved in condition if reached by a mine; but even at a short distance from the outcrop, it would be at a great depth owing to the high dip. Further to the west of Brehal, the seam again grows thinner. It is last seen in a small stream about ½ mile to the west of the Brehal outcrops, and is only 2 feet 2 inches thick, but with a lower dip, 37° to S. 20° W.

To the south of Brehal the dip of the rocks overlying the coal, as may be seen from the accompanying section, is very high, as far as the Tawi, and in the level ground near the river, the coal seam must be at a great depth beneath the surface;

but it might be worth while to make a boring to the south of the river near the village of Kahiar, which is almost in a line with the sharp anticlinal ridge of *great limestone* at Kroli, and where the coal measures may be brought up within a reasonable distance of the surface.

b. The Sujanpur synclinal.

Ascending the hill side to the north of Brehal over *great limestone* and breccias, coal is next found about ½ mile to the west of the tank at Chakar, at the base of a scarp formed of coal measure rocks overlaid by *Murree sandstones*. When first seen, the seam is only 1 foot thick, and appears to die out entirely to the west where the coal measures bend down towards Brehal over the top of the main anticlinal (*vide* section).

To the east, the seam increases gradually in thickness as far as a point about 100 yards north of the tank, where it is from 4 to 5 feet thick. Here the coal measures bend to the north along the gully leading to the head of the Sujanpur valley, the thickness of the seam again decreasing until it is only 1 foot 4 inches at a point about 800 yards north of the tank. Beyond this, it disappears as a seam, and is represented at intervals by highly carbonaceous shales with lenticular beds or pockets of coal as at the top of the *col* above Sujanpur, and again about half way down the valley on the north side. Towards the lower end of the valley no coal is seen, but the coal measures are much concealed by talus from the steep ridge of limestone to the north.

At the village of Saroda-bar, on the top of Sangar Marg hill, is a small outlying patch of coal measure rocks which occupies the head of the Sujanpur synclinal, and has hitherto escaped denudation. The outlier is of no great extent, and its position at the top of the hill probably renders it worthless for mining purposes, just as at Kala Mitti, the amount of coal exposed by the denudation of the seam is apparently large, but this appearance is rather deceptive.

c. The Ikni and Paddar outcrop.

At the lower end of the Sujanpur valley, the band of coal measures makes another sharp bend round the western end of the narrow ridge of *great limestone* to the north, and runs due east in the direction of Ikni. It is probable that a fault exists along this line which has dropped the lower part of the coal measures out of sight in places; but even where fully exposed, until the ravine close to Ikni is reached, no coal is seen in them. The dip all along this line is very high, about 60° to the north, and the *Murree sandstones* overlying the coal measures rise into lofty hills directly from the outcrop, so that mines could not be sunk to the north of it so as to reach the coal except at a very great depth; though adits might be driven horizontally in a few places to the south of the outcrop so as to undercut the seam. The thickness of the seam at Ikni is variable, but reaches as much as 8 feet in places.

To the east of Ikni, the coal measures are continued along the same line down the Paddar valley, but are occasionally cut out by the fault, which gradually increases in throw, the *great limestone* to the south of it forming a lofty scarp along the southern side of the valley. Coal is seen about half way between Ikni and Paddar, very shaly and nearly vertical; and again at Paddar village[1] itself, where a few pockets

[1] This village is not in the position marked on the map, but is about 3 miles due E. of Lena station.

occur in vertical shales. Below Paddar, the coal measures are eroded and concealed by talus, but may be traced as far as the Rad stream which joins the Chenab at Arnas. Crossing the Rad stream, they enter the hilly country to the north of it, dipping steeply to the north between *great limestone* on the south and *Murree sandstone* on the north, but appear again on the same line at the junction of the Aus and Chenab, and may be traced for some distance up the valley of the latter river to the east. The coal measures, as a whole, seem to be much thinner here, but the different limestones and shales are all represented, and near the village of Kantan, about 1½ miles east of Arnas, I found a small pocket of coal in them. Beyond Kantan, they again enter the hilly ground to the north of the Chenab, and I did not trace them further; but in this direction the coal appears to be confined to small pockets in the shales.

Condition of the Coal.

In all places where the coal is exposed at the surface, it is found to be in a very friable and flaky condition, crumbling easily between the fingers. This is partly due to weathering, and partly to the crushing the rock has undergone during the folding of the rocks. In order to find out whether the coal improves in the interior of the seam, I had a pit sunk near the tank at Chakar so as to reach the coal where it had been unaffected by weathering: the pit was 120 feet from the outcrop in one direction, and 190 feet in another, and coal was reached at about 30 feet from the surface. The rocks passed through were the following:—

	Feet.
Surface soil about	3
Shales, becoming gradually carbonaceous towards the base, about	13
Hard carbonaceous sandstone, with many nests of iron pyrites, about	4
Highly carbonaceous shales, with pyrites, about	10
Coal	Not passed through.

A good deal of water was met with in passing through the sandstone bed; and as the sappers and miners employed in sinking had no proper appliances for lifting the water, the sinking was a very slow process, and I stopped it as soon as coal was reached. The coal extracted is in a very different condition from that at the outcrop, being hard and compact, and not liable to be broken up by carriage to a distance. It is dull black in colour, with thin veins of brighter coal, and burns without flame in an open fire. The laboratory assay is:—

Moisture	·55
Volatiles, exclusive of moisture	11·48
Fixed Carbon	45·50
Ash	42·47
	100·00

Cakes, but not strongly. Ash, grey.

Pits were also driven into the seam, at Brehal and Ikni, to a depth of 20 feet from the surface, where they were stopped by water collecting in them. In these the quality of the coal showed no improvement, but they were not driven far enough to decide the question. The rocks at these places are more highly inclined and crushed than at Chakar, so that it is not likely that the coal would improve within so

short a distance from the outcrop as at that place. In the Bugoola valley,[1] the crushing was probably not so great; and here the coal in the interior of the seam would probably be found similar to that from Chakar.

II.—THE MEHOWGALA FIELD.

Distribution of the coal measures.—In the valley of the Neari Tawi, a small stream running due south about 8 miles to the west of Sangar Marg, between the villages of Acker and Mehowgala, the *great limestone* is again brought up to the surface on the line of the sharp anticlinal north of Sujanpur, forming a dome-shaped mass in the centre of the valley, through which the Neari Tawi passes in a deep narrow gorge. The coal measures, with the overlying *Murree sandstone*, are exposed on all sides of this central mass, dipping away from it in every direction. The dip of the rocks is, as a rule, much less than in the Sangar Marg field; and if the coal seam were fairly constant in thickness, it could be worked under much more favourable conditions than in that area. Wherever the seam is exposed, however, it is found to be very irregular, sometimes thickening out within 30 or 40 feet, from 2 to 5 feet, and thinning as abruptly. At the same time, such lenticular beds of coal seem to be fairly numerous, and no doubt in the aggregate contain a large amount of coal.

The rocks forming the coal measures are of about the same total thickness as in the Sangar Marg field, as shown in the vertical section at the beginning of this report, but there are some changes in the minor beds. Thus the breccias at the base are absent, and the pisolitic clays overlying them are replaced by a hardened clay rock which is locally carbonaceous, and contains thin strings and lenticular beds of coal. These are well exposed at the village of Mehowgala itself, and on the paths leading down from it to the Neari Tawi. There are also two seams of coal about the horizon of the seam in the Sangar Marg area, with a thickness of about 20 feet of shale between them, but the upper seam is apparently never more than 2 feet thick and is generally less.

To the west of Mehowgala, the strata are so horizontal that the stream in the iro valley has cut down through the overlying *Murree sandstone*, and exposed the coal measures. The valley is a broad open one, and the upper portion of the coal measures occupy the greater part of its floor, but the horizon of the coal seams has been reached only near the head of the valley. Here the lower seam has a fairly

[1] NOTE.—Specimen from a pit near Bugoola gives:—

Moisture	·17
Volatiles, exclusive of moisture	8·67
Fixed Carbon	39·13
Ash	52·03

Cakes. Ash, light reddish-grey.

This and the above assay must be considered as very disappointing owing to the large quantity of ash: and if they could be relied on as indicating the average quality of the coal would be in themselves a death-blow to the hope of getting a serviceable fuel from this area. Such analyses, however, being made on a very small portion of the coal are apt to be misleading; and before condemning the whole seam, I would recommend that a sufficient quantity of coal for trial in a steam engine should be raised from the 10-foot pit at Bugoola, and sent down for experiment on the Jummu railway construction.

constant thickness of about 2 feet, with many lenticular beds of a greater thickness. One of these that I measured was about 60 feet long thickening from 2 feet at either end to 5 feet in the centre.

In the Neari Tawi valley, coal is exposed on the path leading from Acker down to the river, but here also it occurs in lenticular beds. In the bed of the river, the coal measures are concealed by gravels and boulder drift. In the vicinity of the central mass of limestone, both on the north and south, there is some local faulting, and the strata are a good deal disturbed; but further up and down stream, the dip settles down more regularly to the north and south respectively. Borings might be made, say, ½ mile from either end of the narrow gorge, to find the depth of the seam.

Condition of the Coal.—At the outcrop the coal is in the same flaky and friable condition as at Sangar Marg, but as the rocks have undergone very little folding, it no doubt improves in the interior of the seam.

The Golan Stream.—Between the Sangar Marg and Mehowgala fields, the coal measures are brought to the surface in the narrow valley of the Golan stream about a mile above the place where the path from Kotla to Mehowgala crosses it. The horizon of the coal seam is not exposed, the lowest rock seam being the lower band of nummulitic limestone, which forms a dome-like ridge on the right (W.) bank of the stream, but a boring of no great depth would reach the coal if present. The rocks, however, are much folded, and the coal could not be worked to any great distance.

GENERAL REMARKS.

It would be very difficult to give a satisfactory estimate of the total quantity of coal available in these fields, at any rate until the thickness of the seam has been thoroughly tested by boring; and I shall not attempt to do so. My opinion is that there is a large amount of coal, but spread over so large an area that the average thickness of the seam is not great. Whether it would be profitable to work a seam only 2 or 3 feet in average thickness, must depend on the demand for coal in the Punjab, and the distance of the nearest railway line. A large initial outlay would have to be incurred in any case in making borings and sinking pits on a European system before any coal could be extracted, as it would be very unadvisable to work the coal from the outcrops, as might be done if the strata were more horizontal.

As it is impossible to mark the sites I have selected for borings in so small a map as the 2 miles = 1 inch which is the largest at present available, I append a table giving a list of the different places in which borings might be made, with the rocks exposed at the surface in which the borings would be commenced, and the dip of the rocks. Most of these I marked in the field with a small cairn of stones as a guide to the engineer who will superintend the borings. These are marked with an asterisk. As a rule, I have chosen them in such places that the coal should be reached at a moderate depth; but afterwards, if these are successful, other borings might be made at greater distances from the outcrop. In any case, the borings I have indicated should, I think, be made before any expense is incurred in sinking pits.

LIST OF BORING SITES.

Sangar Marg Field.

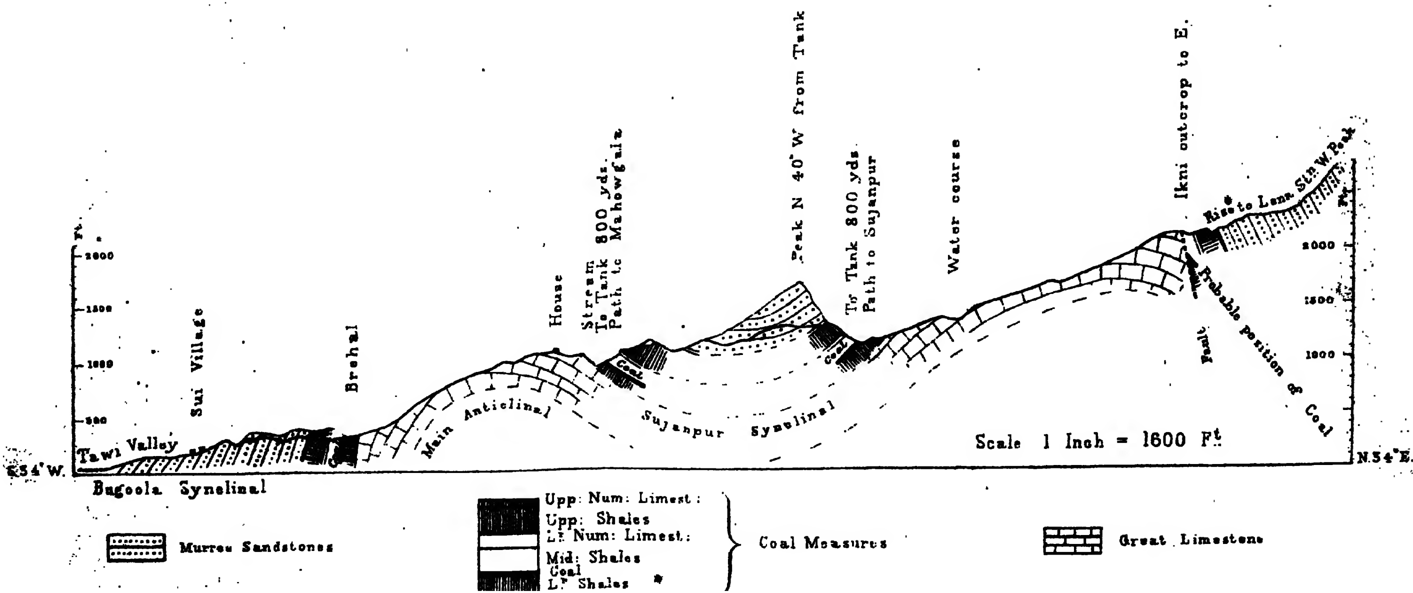
Locality.	Beds exposed at surface.	Direction of dip.	Angles of dip.	REMARKS.
1* Kroli village, at side of path on *col* leading to Tawi valley.	C.M. upper shales	S.W.	67°	Coal exp. about 80 ft. to N.
2. Kahiar village, in ravine to E. of village.	M.S.S.	S. 20° W.	62°	
3* About 500 yards S. of Ransu village, on path from Berh to Kotla at side of small stream.	M.S.S.	?	?	Rocks at surface not well exp.
4. Near conical hollow on fields about 200 yards S.W. of Ransu.	.....	...	...	Rocks concealed by cultivation.
5. In bed of Tawi stream by 2nd mill below gorge at Ransu.	......	...	...	Rocks concealed by boulders in river.
6* Bugoola valley, about 300 yards S.W. of Kori, Gulabgarh fort W. 7° N.	M.S.S.	S.	50°	
7* Between Kori and Ransu, about 30 ft. S. of path on top of *col*.	C.M. middle shales.	S.	40°	
8. Brehal side of stream about 100 yards S. of coal outcrops.	C.M. upper shales	S.	70°	
9* Chakar in ravine about 500 yards W. of tank, Lena Stn. N. 30° E.	C.M. lower portion of upper shales.	N. 20° E.	30°	
10* Chakar, about 300 yards N. of tank, Lena stn. N. 25° E. Peak above Berh S. 35° W.	Do. do. do.	Approx. horizontal		

Mehowgala Field.

Locality.	Beds exposed at surface.	Direction of dip.	Angles of dip.	REMARKS.
11* In valley N. of Acker village, about 1½ miles from Neari Tawi Mehowgala due W.	C.M. near top of upper shales.	S. 25° E.	44°	
12* In bed of Neari Tawi, about 100 yards below crossing of path from Acker to Mehowgala	C.M. top of middle shales.	S.	36°	
13* W. of Mehowgala village, where path to Siro turns S. along base of scarp of M.S.S.	Base of M.S.S.	W.N.W.	6°	
14* In ravine on path to Siro from Mehowgala.	C.M. top of upper shales.	Approx. horizontal		
15* In same ravine E. of Siro village	C.M. upper shales	Do.		
16* On left bank of Siro stream below the village near junction with small stream from W.	C.M. upper shales	S.S.W.	17°	
17* About ½ mile W. of Siro village in valley of small tributary stream.	C.M. upper shales	Approx. horizontal		

M.S.S. = *Murree Sandstones.* C. M. = *Coal measures.*
N.B. - The bearings throughout are *compass bearings.*

SECTION ACROSS SANGAR MARG COAL FIELD FROM BREHAL TO LENA STN.



RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1888. [August.

The Manganese-iron *and* Manganese-ores *of* Jabalpur, *by* PRAMATHA NATH BOSE, B.Sc., F.G.S., *Deputy Superintendent, Geological Survey of India*. (With 2 maps.)[1]

The *pyrolusite* of Gosalpur was first brought to the notice of Government by Mr. W. G. Olpherts in 1875. It was examined in 1879 by Mr. H. B. Medlicott, late Director of the Geological Survey, and a note on the ore, with an analysis of it by Mr. Mallet, was published in the "Records" of the Survey for that year (Vol. XII, p. 99). Four years later Mr. Mallet examined the iron-ores of the northern portion of the district of Jabalpur. In his very valuable and comprehensive paper on those ores ("Records," Vol. XVI), there is a brief notice of the Manganese-ores of Gosalpur. He was, I believe, the first to point out the existence of *psilomelane* in association with manganiferous hematite, the latter forming a band in the Lora group[2] at Gosalpur and Khatola.

In 1884 Mr. C. W. McMinn, then Deputy Commissioner of Jabalpur, sank a number of pits to ascertain the extent of the manganese-ores at Gosalpur. In the same year Dr. King, the present Director of the Survey, paid a hurried visit to the place from Jabalpur. During the Durga Puja holidays last year, the ores were further explored by Mr. E. J. Jones of the Geological Survey. After Mr. Jones' return, I was deputed by the Director about the middle of October last to continue the exploration.

On arrival at Gosalpur, I found a number of pits and trenches excavated by Messrs. McMinn and Jones, of which Mr. McMinn's pits had been partially filled up. I had these cleaned, and, where necessary, deepened, and started a number of fresh excavations in different parts of the village. I found that the *pyrolusite* occurred in

[1] Map 1 only published now: Map 2 will appear in next number of the Records.

[2] One of the groups into which the Bijawar formation has been divided, called after the Lora range near Sihora. (*Vide* Records, Vol. XVI, p. 96.)

and among quartzites,[1] which were subsequently found to invariably accompany the Lora group, forming probably its base, and which, for the sake of convenience, I have designated as Gosalpur quartzites. I found, also, that the Lora group formed a distinct synclinal just west of Gosalpur, the manganiferous and other Lora strata which crop out here re-appearing in the Chakrandha hill, a mile and a half west of Gosalpur, but with the dip reversed. With these clues I traced the *psilomelane* and *pyrolusite* over a rather wide area, included partly in Sihora and partly in Jabalpur Tahsil. But though spread over such a large area, the quantity of *pyrolusite* does not appear to be so great as might be expected. I must observe, however, that none of the localities was searched so minutely as Gosalpur; and that the present report is to be taken rather as indicating the directions in which *pyrolusite* or *psilomelane* is to be looked for, than as giving an exact, or even an approximately exact, estimate of the ore-bearing capabilities of the entire area. However, enough has, I venture to think, been done for exploration purposes in the northern portion of the Bijawar ground. With regard to the southern Bijawar ground, west and south-west of Jabalpur, I had time only to pay a hurried visit to it. I found *psilomelane* in the Lora group at Nonsar, 12 miles north-north-west of Jabalpur, on the road to Patun. The Lora group also occurs at Gangai (a short distance south of the Marble Rocks near Jabalpur); and it is possible that both *pyrolusite* and *psilomelane* will be found in it. I would recommend that the unspent portion of the manganese exploration fund, amounting to R75-7, be devoted to the exploitation of this area.

The Central Provinces Government made a grant of R500 for the manganese exploration at Gosalpur. When I found that the ores extended far beyond this place, I tried, by exercising strict economy, to make my work cover the entire area without exceeding the grant; R450 only was drawn by me, and of this amount an unspent balance of R25-7 has been deposited with the Deputy Commissioner of Jabalpur.

I have to record my thanks to Messrs. C. W. McMinn and F. C. Anderson, Commissioner and Deputy Commissioner, respectively, of Jabalpur, when I started work, for the readiness with which they gave me every assistance that lay in their power. The Director paid an inspection visit while the exploration was in progress; and, if it may be called successful in any sense, not a little of the success is owing to his guidance and encouragement.

I have in this report tried to present the economic results of the exploration. Observations which are chiefly of theoretical interest will be discussed in a separate report, which will be submitted to the Director later on.

I. Manganiferous Hematite and Psilomelane.

A.—Manganiferous Hematite.

The manganiferous hematite is confined almost exclusively to the Lora group. There is one doubtful occurrence, which will be specially noticed hereafter. The normal and original form of the ore appears to be that known as micaceous-iron-ore, layers of which are interbanded with thin jaspery quartzites, both contorted together,

[1] There is one exception, see p. 82.

and the former curiously following the flexures (which are sometimes very sharp) of the latter.

The micaceous-iron-banded quartzite, *i.e.*, quartzite with interbedded layers of micaceous hematite, is generally too poor to be worked profitably. But at places the micaceous-iron-ore is very rich, the quartzite element being entirely, or almost entirely, wanting. This richness usually takes place on comparatively low ground. The highest points of the ridges are almost invariably formed of contorted quartzites with layers of micaceous hematite.

When the micaceous-iron-ore is very rich, as at the foot of Santok hill (Gosalpur), the rock may be called a micaceous-hematite schist. Such micaceous-hematite schist was seen in the direction of the strike, as well as across it, to pass into the folded quartzose rocks with thin layers of the ore at Dharampur and elsewhere.

The micaceous hematite sometimes passes almost imperceptibly into manganiferous hematite, which appellation is here given to hematite in which the presence of manganese is discernible with the naked eye, for there can be hardly any doubt that this mineral is also present in the micaceous hematite, though as mere traces. In proportion as the micaceous-iron-ore becomes manganiferous, it loses its characteristic micaceous lustre, and becomes more earthy-looking and massive. The shales interstratified with, and overlying, or underlying, the micaceous-iron-banded quartzites are also frequently impregnated with manganiferous hematite in varying degrees of richness.

The manganese in the manganiferous hematite is usually present as nests and thread-like veins of *psilomelane*, besides being disseminated in the matrix.

In the Lora hill area (in which I include the entire area stretching from Daimapur to Murhasan), manganiferous hematite in workable quantity was found at the following localities:—

I.—*Dharampur* (*including Hirdenagar*).—Close to the boundary between this village and Deonagar, on the western slope of the ridge running south-west from Gosalpur, a trench exhibited the following section (commencing at the north-western end):—

8′ Soft whitish talcose slaty shales *(chuhi)* dipping north-north-west.
18′ Obscured.
11′ Shales.
18′ Obscured.
32′ Decomposed earthy rocks with traces of micaceous hematite.
24′ Obscured.
13′ Whitish shales with a little micaceous hematite.
28′ Shaly and quartzose rocks with some micaceous-iron-ore.
15′ Micaceous hematite.
3′ Banded jaspery-looking rock, with limonite towards surface, dipping N. 35 W.
6′ Obscured.
78′ Soft, thinly-stratified, whitish and yellowish talcose shales.
13′ Obscured.
32′ Micaceous manganiferous hematite.
10′ Shales impregnated with *psilomelane*.

A trench three-quarters of a mile north-east of this trench, on the road from

Tola Hirdenagar to Dharampur showed the following section, commencing at the north-western end (about 57 feet from it):—

12′ Massive limonite, with segregated *psilomelane* at the surface.
5′ Shaly rocks.
12′ Shaly rocks (rather thick-bedded) with some manganiferous hematite.
33′ Shales (partly obscure).
6′ Manganiferous hematite with *psilomelane.*
16′ Shales with a little micaceous iron-ore.
17′ Manganiferous hematite.
12′ Soft, decomposed, earthy rocks, with micaceous iron-ore.
25′ Soil to a depth of 4′ with fragments of micaceous iron, manganiferous hematite, &c.
6′ Obscured.

A trench about three-quarters of a mile east of the village of Dharampur, and close to the boundary between it and Murta (a deserted village), exhibited a rather rich deposit of manganiferous hematite. Commencing from the north-western end the cross-cut gives the following section:—

28′ Micaceous-iron-banded quartzite (poor).
4′ Manganiferous hematite (with massive *psilomelane* at the surface).
88′ Micaceous-iron-banded quartzite (poor).
30′ Schistose micaceous iron (rather rich).
14′ Micaceous-iron-banded quartzite.
8′ Obscured.
2′ Schistose micaceous iron (rich) apparently much 'crushed,' with abundant *psilomelane.* [The dip observed so far points N.N.W.]
12′ Obscured.
11′ Manganiferous hematite, very rich in *psilomelane,* apparently much crushed.
33′ Micaceous hematite at places rich in *psilomelane.*

A pit dug at this end showed (from the surface)—

2′6″ Large blocks of apparently much crushed manganiferous hematite with abundant *psilomelane.*
3′ Schistose micaceous iron with a little *psilomelane.*

Another pit, 24 feet south-east of last showed from the surface—

2′6″ Large blocks of *psilomelane.*
2′6″ Large blocks of *psilomelane* (but harder) with bits of micaceous hematite.
4′ Schistose micaceous hematite.

II. Gosalpur.—A cross-cut here, a little less than half a mile north-west of the dâk bungalow, gave the following section, commencing a few feet from the north-western end:—

6′ Manganiferous hematite (very rich). *Psilomelane* in large botryoidal masses at the surface.
13′ Manganiferous hematite gradually becoming poorer, southward.
5′ Obscured.
18′ Soft micaceous iron-ore.
8′ Micaceous-iron-banded quartzite. [The dip so far appears very high and points to N.N.W. to N.W.]

25′ Obscured.
43′ 'Crushed' quartzoze rocks with manganiferous hematite, rather rich at places.
8′ Micaceous-iron-banded quartzite.
43′ Schistose micaceous hematite with a little *psilomelane*, dipping N.N.W. 60°.

The cross-cut at the northern edge of the ridge north-west of the dâk bungalow, locally known as Santok hill, about a quarter of a mile north of the bungalow, gave a good section. The trench was dug partly by Mr. McMinn and partly by Mr. Jones. It was deepened by me at places. Commencing at the north-western end the section is as follows :—

7′ Reddish and purplish slaty shales, dipping 55° N.W. by N.
4′ Manganiferous hematite with thin veins of *psilomelane*. The surface of the hematite bed is botryoidal at places, the *psilomelane* veins following the contour of the concretions.
35′ Soft, talcose shales, at places impregnated with iron-ore.
28′ Schistose, micaceous hematite.
8′ Same as above, but blacker, more massive-looking, richer, and with occasional veins and nests of *psilomelane*.
12′ Schistose micaceous hematite.
8′ Micaceous hematite partly with veins and nests of *psilomelane*.
22′ Argillaceous rocks, with some micaceous hematite.
42′ Mottled quartzose rocks more or less obscured at places.

III.—At Pahrewa (a mile and a half south of Sihora) and at Khatola, the manganiferous iron-ore is fairly rich at places. Close to the boundary between Sukra (a deserted village just east of Khatola) and Surda, a trench gave the following section, proceeding from its north-western end :—

230′ Manganiferous hematite, very rich at places.
24′ Covered up.
21′ Manganiferous hematite.
27′ Obscured.
15′ Schistose micaceous hematite.
8′ Obscured.
17′ Micaceous-iron-banded quartzites, much folded and crumpled.

IV. Gogra.—Along the southern slope of the Lora range the manganiferous ore is very rich at places. It is especially so at Gogra, close to, and at, the boundary between this village and Danwai. There are some mines here which have for some time past been supplying the furnaces of the entire neighbourhood.

V.—Mangela (a deserted village).—Here, too, the ore appears to be rather rich. There are some old mines here.

With regard to the other outcrops of the Lora group, manganiferous hematite does not appear to be present, at least to any considerable extent, in the band stretching from south of Chattarpur to Saroli, as well as in the Lamehra range of hills. I am not also aware of its occurrence in the outcrop south-west of Bhera Ghat. Neither of these bands, however, was closely searched.

In the Lora patch at Nonsar (12 miles north-west of Jabalpur, on the road to Patan) manganiferous hematite was found to exist.

B.—PSILOMELANE.

This mineral is present, as has been already mentioned, as fine thread-like veins in the manganiferous hematite. Sometimes a bed of this hematite has developed on it botryoidal concretions, which increase in size towards the surface so as to become large mammillary masses. The *psilomelane* veins follow the contour of the concretions, and increase in number and thickness towards the outcrop, so as to appear as nearly mammillary masses of pure *psilomelane* at the surface.

This kind of change was specially observed to take place in the comparatively thick shaly strata overlying the micaceous-iron-banded quartzite. The development of *psilomelane* in these was found associated with that of milk-white quartz rocks at some places.

In the manganiferous hematite, formed evidently by the local concentration of disseminated *manganese* in the schistose micaceous-hematite, *psilomelane* usually appears as thin veins, parallel to bedding or filling small fissures, &c. Sometimes an outcrop of micaceous-hematite schist, with dip and strike quite distinct, is abruptly overlaid by botryoidal or mammillary masses of pure *psilomelane*. Usually, however, there intervene between the two a mass of variable thickness composed of bits of manganiferous hematite cemented together by a matrix of *psilomelane*, the whole mass looking as if the hematite had been crushed, and the broken fragments subsequently welded together by the manganese-ore. This is the view held by Mr. Mallet. Wherever, however, the apparently crushed mass was dug into, it was found to pass gradually downward, within sometimes not more than 4 or 5 feet from the surface, into strata which showed no signs of crushing at all, and which, in fact, at places, as at Murhasan, were found to dip rather easy. This appearance of "crushing," at or near the surface, may, it appeared to me, be attributed to surface disintegration of the micaceous-hematite previous to the deposition of *psilomelane*; or, as suggested by Dr. King, to the expansive force exerted during the development of *psilomelane*; or in part to both.

Psilomelane co-exists with manganiferous hematite; and the places where the latter has been found in abundance are also the localities where the former occurs in any quantity.

At Murhasan, there occur thinly-stratified quartzites without any interbedded micaceous hematite. They are superposed by massive quartzose beds which are highly ferruginous. There is considerable twisting of the strike, and the rock which crops out has an appearance of being very much crushed. The shivered fragments of quartzite are cemented by *psilomelane*, and at one spot by *pyrolusite* as well.

At Ponri (4 miles west of Sihora) banded quartzose strata without any micaceous hematite, similar to those just mentioned as occurring at Murhasan, considerably twisted, have developed in them, towards the surface *psilomelane* as thin veins, fillings in of fissures, &c. The *psilomelane* does not appear to go down more than 4 or 5 feet from the surface. The quartzite appears to be converted towards the surface partly into limonite and partly into *psilomelane*. The *psilomelane, in situ*, is very much mixed up with the matrix of the quartz-rock, but nodules of it found along the hill slope are nearly free from it. This fact of the nodules of detrital ore being much richer than the ore *in situ*, was observed almost everywhere. Sometimes blocks rich in

manganese-ore were found along hill slopes, but the search for the ore *in situ* from which the blocks may have been derived proved fruitless.

The quartzose strata after an interspace of about a mile re-appear north-east of Darsani, richly impregnated with *psilomelane* and other manganese-ores. They form a ridge running in the direction of strike for about 2 miles. The manganese and iron-ores here are very much mixed together. The former predominate in the hill just north-east of Darsani, as also on Kasai (or Kushi) hill. A pit opened on the south-eastern slope of the former exhibited some 16 feet of the ore, which appears to be mostly *psilomelane*. In the Kushi hill a distinct syncline was observed. This hill will be again noticed in connection with *pyrolusite*. The quartzose strata of Ponri, Darsani, and Kushi hill probably belong to the Lora group, and have, in all likelihood, come up by an anticlinal flexure.

A large quantity of *psilomelane* in the form of nodules occurs at Gosalpur (Area *b*, Map of Gosalpur). And a little of the mineral in intimate association with *pyrolusite* also occurs at this place and elsewhere.

From the mode of occurrence of *psilomelane* it is impossible to form anything like an estimate of the quantity present. The quantity of pure *psilomelane* cannot be very great, as it is chiefly confined to the surface. Still it is probably greater than that of *pyrolusite*. The quantity of manganiferous hematite, with veins and nests of *psilomelane*, must, however, be regarded as practically inexhaustible.

An assay of an average specimen of the manganiferous hematite (from Danwai mine) made by Mr. Mallet, gave the following result (Rec., Vol. XVI, p. 101):—

Ferric oxide	66·33	= Iron 46·43
Manganese (with traces of cobalt)	12·26	
Oxygen	6·83	
Phosphoric acid	·27	
Sulphuric acid	·03	
Sulphur	trace	
Ignited insoluble residue	9·55	
Lime, alumina, water and undetermined	4·76	
	100·03	

The ore would be useful for the manufacture of steel. At present it is used for the manufacture of a kind of a steely iron, known as *kheri*. A brief account of the *kheri* industry will be found in Note A.

A specimen of *psilomelane* analysed by Mr. Mallet yielded 83·20 per cent. of the available peroxide.

II.—Pyrolusite.

Its distribution is generally co-extensive with that of the Gosalpur quartzites.[1] At places, however, the mineral is present as mere traces. It was found in any quantity at the following localities:—

1. *Gosalpur*—Except in the ground just in front of the dâk bungalow (some 50 yards to south-east of it), the *pyrolusite* occurs here in and among the Gosalpur quartzites, usually soft, decomposed, and blue-coated at the outcrop. Sometimes the rock is hard, and either white or red in colour, assuming in the latter case the

[1] A band underlying, and probably forming the base of, the Lora group.

appearance of jasper. Wherever such is the case, manganese-ores are wanting. Frequently the rock appears as a conglomerate or breccia, fragments of soft, decomposed (sometimes almost powdery) quartzite being cemented together, as it were, by a matrix of *manganese* or iron-ore. Wherever such a rock crops out, *manganese* or iron-ore is found in some quantity by digging close to it through the soil-cap under which it passes, the nature of the ore being determined by that of the "matrix" at the outcrop.

The quartzites have the general Bijawar strike of the area, *viz.*, N.E.-S.W., The dip is obscure; it was found to be very high (about 80°) pointing S.E., some 150 yards north of the dâk bungalow.

The details of some of the sections as exposed by the pits (see Map of Gosalpur) at this place may not be uninteresting. The great majority of them may be grouped in two lines, 250 to 500 feet apart, running nearly E.—W., roughly parallel to each other.

Commencing with Pit No. XIII, at the western extremity of the southern line of pits, the sections are as follows :—

Pit XIII.

1′5″ Soil with grains and nodules of iron-ore.

6′ Large blocks of hematite, some with fragments of decomposed quartz rock passing below into decomposed quartzites with veins of hematite.

Pit XIV.—One hundred and seventy-five feet east-north-east of last pit. It is an old, large, squarish pit, measuring 23 feet east to west. At its northern end there is an outcrop of the Gosalpur quartzites, either coated blue or having the appearance of a "breccia," such as has been described above. The pit was deepened at two ends to 30 feet at the western, and 12 feet at the eastern end.

1′ Soil with blocks of quartzite.

1′ Grains and nodules of iron-ore, with a few occasional grains of *pyrolusite* and fragments of quartzite.

5′6″ Abundant *psilomelane* in flat, platy masses, with which are associated *pyrolusite* and hematite as grains and nodules.

The shaft at the western end of the pit disclosed below the last-mentioned layer a thickness of—

22′6″ of decomposed, rotten, crumbly, whitish, yellowish, and mottled speckled quartz-rock with veins and nests of *pyrolusite*, passing below into similar decomposed speckled rock, but without these veins and nests. Small pockets of well-crystallised *pyrolusite* were found, however, in the latter at various depths. The speckled appearance is due to the presence of brownish specks, which will be described hereafter.

Pit XIX.— Two hundred and twenty-five feet to east of last—

6″ Soil.

3′6″ Platy, flat and botryoidal masses of *psilomelane*, with some *pyrolusite* (the former predominating largely), and grains and nodules of iron-ore.

4′ Decomposed yellowish and mottled quartz-rock, with veins and nests of *pyrolusite* and *psilomelane*.

Pit XV.—Fifty feet east of last—

1′ Soil.

4′ Nodules and grains of iron-ore, and of *pyrolusite* largely associated with *psilomelane.*

4′6″ Yellowish decomposed quartz-rock with nodules of earthy-looking *pyrolusite* (?).

3′ Yellowish, decomposed, quartz-rock, with veins and nests of *pyrolusite* (?), which disappear towards bottom.

Pit III.—Two hundred feet east-south-east of last—

1′ Soil.

6″ Nodules and grains of iron-ore, with a little *pyrolusite* towards base.

3′ Grains and nodules of iron-ore and of *pyrolusite*, the latter measuring $\frac{1}{8}$″ to 2″ across, and associated with *psilomelane* (but not so largely as in the previous pits).

3′6″ Decomposed quartz-rocks with grains and nodules of *pyrolusite.*

Pit XXVIII.—One hundred feet east of last—

3′ Soil.

2′6″ Nodules and grains of *pyrolusite* and of iron-ore, the former averaging probably less than $\frac{1}{2}$ inch in diameter.

1′ Large blocks of very good *pyrolusite,* somewhat spongy in texture, with cavernous spaces occupied by yellowish, decomposed quartz-rock.

1′2″ Decomposed yellowish and yellowish-white mottled quartz-rock, with veins and nests of *pyrolusite.*

Pit XXXI.—One hundred and ten feet east of last.—This is one of three pits sunk in a large, old, partially filled-up pit, from which *pyrolusite* used to be raised of old by glass-makers.

2′ Soil.

2′8″ Abundant nodules of *pyrolusite,* $\frac{1}{4}$ inch to 6 inches in diameter, mixed up, as usual, with nodules of iron-ore. A little *psilomelane* and *wad* occurs in association with the *pyrolusite.*

4′10″ Fragments of decomposed yellowish, and yellowish-white, mottled quartz-rock, becoming larger and more abundant towards bottom. *Pyrolusite* occurs in the interstices in larger blocks than in the preceding stratum and with cavernous spaces containing the decomposed quartz-rock.

Decomposed quartz-rock with veins and nests of *pyrolusite.*

Pit XLVI.—Seventy-five feet south-east of last—

2′4″ Grains and nodules of iron-ore.

3′10″ Yellowish and brown mottled ferruginous grit, or gritty clay, in large blocks.

6″ Spongy nodules of *pyrolusite* with decomposed quartzite.

Pit XLVII.—Fifty feet south-east of last—

9′ Yellowish and brown ferruginous grit, or gritty clay, without a trace of *pyrolusite.* The rock was found so hard that it had to be blasted.

Pit XXV.—Five hundred feet east-north-east of last, in the Bazar.

3′ Soil.

4′4″ Hard, yellowish loam, with grains of *pyrolusite* and iron-ore.

12′ Nodules and grains of iron-ore, at places compacted into large, hard blocks with abundant oolitic grains (internally black, *pyrolusite* ?), and a few large nodules of hematite and of *pyrolusite.*

Decomposed quartzite with veins and nests of hematite.

Farther east, a section, some 20 feet in thickness, is exposed in an old *baoli*, opposite the police station. The entire depth consists of ferruginous, more or less cellular, gritty clay (Laterite).

The northern line of the more important pits alluded to before may be taken to commence with Pit XX, 225 feet north-west of Pit XIII (the westernmost one of the southern line of pits just described).

4′ Soil with small grains and nodules of *pyrolusite*, averaging ½ inch in length, and big lumps of hematite (some with segregations of *pyrolusite*).

2′8″ Decomposed, crumbly, yellow and white mottled quartzite.

Pit XXXV.—One hundred and seventy-five feet east-north-east of last—

4′ Soil with fragments of quartzite, and grains and nodules of *pyrolusite* and of hematite (a little *pyrolusite* and *psilomelane* being associated with the latter). The nodules, as usual, are generally of a spongy texture.

Pit XXII.—Five hundred and seventy-five feet east of last—

9″ Soil with small grains and nodules of *pyrolusite.*

1′9″ Abundant *pyrolusite* in nodules, and small angular and irregular plates, with fragments of quartzite and grains and nodules of iron-ore.

1′6″ Large blocks of *pyrolusite* with decomposed quartzite.

1′ Blocks of yellow and mottled decomposed quartzite with *pyrolusite*, occupying interstices between them.

Pit XLIII.—Two hundred and fifty feet east of last—

8″ Soil.

5′ Nodules and grains of iron-ore and fragments of quartzite. Towards bottom, large spongy blocks of hematite with decomposed quartzite.

Decomposed quartzite.

Pit XXVI.—Six hundred and twenty-five feet east-north-east of last—

8′ Small grains and nodules of iron-ore with big lumps of hematite of a spongy texture, associated with a few small nodules of *pyrolusite*, the latter being quite subordinate.

2′6″ Decomposed yellow and white quartzite, with veins and nests of hematite and *pyrolusite* (?).

The ground lying to east of this pit is covered by nodular iron-ore compacted into hard rock (Laterite), forming a somewhat high ground. At the foot of this ground, 1,075 feet east-north-east of Pit XXVI, an outcrop of quartzite was met with in Pit XXVII, with veins of hematite. In a well, a few yards from this pit, reddish and white mottled quartzose shales were met with at a depth of 4 feet from the surface.

North, south and east of the area enclosed by the two lines of pits described above, the ground is covered by nodular iron-ore usually compacted into hard rock. Some pits were sunk into it. Several in the northern portion of the ground, disclosed, at a depth of about 9 feet or so, decomposed quartzites similar to the rocks invariably found at the bottom of the pits described above when deep enough.

In the ground west and north-west of the dâk bungalow, the rock found below the nodular iron-ore (which is of small thickness) is a ferruginous, red and yellow and brown grit or gritty clay, similar to that found in Pit XLVII. About 50 yards

east and south-east of the dâk bungalow, a few fragments of slaty-looking micaceous hematite were found mixed up with the nodular iron-ore. A trench varying in depth from 6 to 12 feet, disclosed the former rock *in situ*, but to all appearance very much crushed, fragments of it being held together by a ferrugino-*manganiferous* cement. This rock passes into a lateritic-looking rock containing iron-ore and *manganese*-ore (*pyrolusite* intimately associated with a little *psilomelane* and iron-ore) in which not a trace of the micaceous hematite was observable. A large quantity of *manganese*-ore was raised from this trench. That its occurrence, however, is exceptional, is evidenced by the following section disclosed by a pit (XVI) in front of the bungalow, not many yards from the trench just mentioned :—

5′ Nodular iron-ore.
8′ Blocks of hematite with bits of micaceous iron-ore.
10′ Soft, earthy, micaceous hematite.
4′ Compact and very hard red hematite, so hard that it had to be blasted.

The *pyrolusite* area of Gosalpur is divisible into five portions (see Map 1) :—

(*a*) Stretching east-west from Pit XLVI to Pit XV, and north-south from a point a few yards north of Pit XXII to a point between Pits III and XV. Here the *pyrolusite* is the predominating mineral, *psilomelane* and iron-ores being quite subordinate to it. The greatest thickness of the ore-bearing stratum (leaving out of consideration the quartzites with veins and nests of *pyrolusite* as unworkable with profit) is 7 feet 6 inches (Pit XXXI), and the least 1 foot (Pit XXXIII, not described above). The former thickness is, however, somewhat exceptional, and the mean should probably be taken at not more than 3 feet 6 inches. Towards the surface, the *pyrolusite* nodules are mixed up with those of iron-ore, and towards bottom, they contain a good portion of the matrix of the quartzite, in which it occurs as veins and nests deeper down. The quartzite is, however, much decomposed, loose and crumbly, and is, therefore, easily separable. Making allowance for it and for the grains and nodules of iron-ore, it would not be safe to take the thickness of pure *pyrolusite* (associated with a little, but very little, *psilomelane*) at more than 1 foot 6 inches.

The greatest length of the principal *pyrolusite* area is 525 feet, and the greatest breadth 338 feet. The area is about 157,500 square feet. There are several small outcrops of the Gosalpur quartzites within this area; and the *manganese*-ore is present in them as mere traces. The area covered by them cannot be less than 20,000 square feet. Applying this correction, the estimated *pyrolusite* area would be reduced to 137,500 square feet. Thus the quantity of *pyrolusite* present here would occupy $137{,}500 \times \frac{3}{2}$ cubic feet$=206{,}250$ cubic feet.

The specific gravity of an average specimen of the *pyrolusite* from this area, determined in the laboratory of the Geological Survey, was found to be 4·7. Thus the weight of the quantity available here would amount to 27,000 tons (about).

It should be observed that a portion of this amount (by no means inconsiderable) has been taken away from the old pit (the richest portion of the ground between Pits XXX and XXXI) by glass-makers and others; and that a portion has been raised from the trial excavations successively made by Mr. McMinn, Mr. Jones and myself, and is lying at the place.

The cost of raising the ore is trifling, as it occurs at a very low depth from the surface, and can be dug out with facility. It should, however, be observed, that

a large portion of the ore occurs in small grains, coated red by oxide of iron; and the sifting of these from similar grains of iron-ore needs time, care, and experience. The proportion of larger blocks and nodules of *pyrolusite*, measuring from nearly a foot to half an inch in length to smaller grains was found in Pit XXVIII to be nearly 1 to 3. So that the former kind of ore in the area under consideration does not probably amount to more than 9,000 tons. Of this amount, that already removed may be put down at about 500 tons, if not more. So that the quantity still available of the larger nodules of the ore (above half an inch in length) probably does not exceed 8,500 tons. This estimate is no doubt very vague, and it is given here, as it may give a better idea of the quantity of the ore available than mere guesses.

(*b*) In this area, the *psilomelane* either predominates over the *pyrolusite*, or the two minerals are present in about equal proportion. It stretches south-westward from Pit XV. Its length may be taken at about 470 feet, and breadth at about 80 feet. Thus the area may be estimated at 37,600 square feet. Making allowance for an outcrop of the Gosalpur quartzites, in which the *manganese*-ores occur as mere traces, or do not occur at all, this estimate would be reduced to probably 24,000 square feet. The greatest thickness of the ore-bearing stratum is 8 feet 6 inches (Pit XV), and the least 3 feet 6 inches (Pit XIX). A mean of 5 feet may, I think, be safely taken. The ore, however, is mixed up with grains and nodules of iron-ore. Making allowance for these, the manganese-ore (*pyrolusite* and *psilomelane*) may be taken to occupy a thickness of $2\frac{1}{2}$ feet. Thus the volume of the manganese-ore would amount to $24{,}000 \times \frac{5}{2} = 60{,}000$ cubic feet.

Of this volume not less than half, probably more, say, about three fifths, would be occupied by *psilomelane*. The cubic contents of the *pyrolusite* would thus be about 24,000 cubic feet. Taking its specific gravity at 4·7, it would amount to 3,000 tons (about).

If allowance be made for small grains of *pyrolusite*, this quantity would be still further reduced.

(*c*) (*c*[1]) Two detached areas, one situated north of (*b*), and the other in the village, are included in these divisions. Here the *pyrolusite* is present as nodules or small grains, quite subordinate to similar nodules and grains of iron-ore (hematite, &c). From pits XXV and XXVI (inside the village) only a few nodules of *pyrolusite* of any size were obtained, it being present chiefly as oolitic grains, too small probably to be profitably sifted from similar ones of oxide of iron (both being coated red outside), and worked for purposes for which pure, or tolerably pure, *pyrolusite* is required. It is impossible to form even such a vague estimate of the quantity of *pyrolusite* present in these two areas as has been given for (*a*) and (*b*). It would probably not amount to more than what has been estimated to occur in (*b*).

(*d*) In front of the dâk bungalow, by the road leading from it to the Mirzapur road. Here the *pyrolusite* occurs in "lateritised" micaceous hematite. The iron and manganese-ores are greatly mixed up (the former appearing to predominate). However, a large quantity of blocks and nodules of *pyrolusite* was raised from the trench mentioned before. The area covers about 40,000 square feet. The thickness of the *pyrolusite* may be taken at a fourth of the entire thickness, which is over 12 feet. Thus the cubic contents of *pyrolusite* here would amount to about 120,000

cubic feet. Taking specific gravity at 4·7, the quantity would be about 15,000 tons. The *pyrolusite* here is invariably and intimately associated with a little *psilomelane* and a little iron-ore. The whole of the ore, however, occurs in large blocks and nodules.

Thus the total quantity of *pyrolusite* occurring at Gosalpur may be roughly estimated at about 50,000 tons. It must be remembered, however, that it is almost invariably associated with a little *psilomelane*, and that a good portion of this quantity consists of very small grains, mostly coated red outside by oxide of iron.

2. Keolari (*a deserted village*).—There is an outcrop here of what appeared to me the Gosalpur quartzite, a mile nearly due south of the dâk bungalow at Gosalpur. The quartzite runs parallel to a band of "lateritised" micaceous hematite, similar to that occurring in front of the Gosalpur bungalow, but without any *pyrolusite* as far as ascertained by a trench dug close to the road leading from the Mirzapur road to Khumarea. The quartzites are surrounded, as at Gosalpur, by nodular iron-ore compacted into large, hard blocks at places. Their outcrop is about 600 yards long and 150 yards broad. At the north-eastern edge of it, where they pass under alluvium, some pits were sunk, which disclosed a large quantity of manganese ores. A good portion of these is *wad*; very little *pyrolusite* was found.

3. Murhasan.—This place is situated at the south-eastern extremity of the eastern portion of the Lora Syncline.[1] At the northern edge of a hillock just west of the village, apparently much crushed quartzites crop out with veins and nests of *pyrolusite*. A pit here exposed a thickness of 3 feet of large nodules of *pyrolusite* of a somewhat spongy texture, passing below into quartzose rock with a network of veins of *manganese-ore* as in the Gosalpur pits. The *pyrolusite* is associated with *psilomelane*; and the rest of the hillock is constituted of contorted Lora strata in which the latter mineral is alone found. The *pyrolusite* area here is probably not more than 625 square feet in extent. Much of the ore, however, is mixed up with the quartzite in which it occurs. The quantity of *pyrolusite* here would not probably exceed 200 tons.

Proceeding north-eastward from Gosalpur along the eastern side of the Lora syncline, the next notable occurrence of *pyrolusite* is at 4.—*Pahrewa*, a mile and a half south of Sihora. The mode of occurrence of the ore here is somewhat similar to that at Murhasan. It was found on a conical hillock just south of the village (which is very nearly deserted) to the left of the Mirzapur road. A pit on the western slope of this hillock disclosed 7 feet of decomposed quartzites, with considerable nests and thick veins of *pyrolusite* (associated with *psilomelane*). A trench a few yards north-east of the pit, however, at the top of the hillock, exposed apparently crushed quartzose rocks, micaceous hematite, and manganiferous hematite with veins of *psilomelane*.

5. Khatola (*Kuthola on map*).—The *pyrolusite* here occurs in two hillocks formed of the Gosalpur quartzites, close to the railway station. The quartzites are worked for railway ballast, and a portion of the *pyrolusite* has gone with it. I pointed out the ore to the contractor working the ballast pits, and verbally told him

[1] The syncline formed by the Lora group, well seen just west of Gosalpur, and more or less distinctly traceable south-eastward to Murhasan and Kailwas, and in the north-western direction to the Lora range proper.

not to carry it off with the ballast. At one spot, in the smaller of the two hills west of the Saroli road, the *pyrolusite* was found in massive, somewhat cellular, blocks at the surface; digging down, however, it was found to get mixed up with the quartzite. The ore is scattered over a good area. But there is probably no considerable quantity of it, as it is confined to the surface, or occurs chiefly as mere traces.

6. Bhatadon (a mile south east of Khatola, on the south side of the Hirun).—Here the ores occur on a small hillock partly composed of the Gosalpur quartzite and partly of lateritic rock. Exceptionally good *pyrolusite* was found at one spot, free from quartzite-matrix. Digging disclosed a thickness of 8 feet of the ore, but mixed up towards the bottom with the quartzite as at Khatola. A few hundred tons of *pyrolusite* may be expected from here.

7. Hargar (2½ miles east of Khatola).—There is a strong outcrop of the Gosalpur quartzites here. The *pyrolusite* was found to occur as mere traces. It was, however, found in some quantity at the south-western edge of a hill situated between Hargar and Daroli. It occurs in association with iron-ores, and the quantity is probably small.

Traces of *pyrolusite* were found at several spots at Danwai (Dunwie) in the low quartzite hills running parallel to the Lora range. It was found, however, in some considerable quantity at:—

8. Mungeli (Mungeilee), close to the road leading from Sihora to Umaria (Oomria).—Five pits north of the road, at the foot of the hill just west of the village, exhibited an average thickness of 2 feet of *pyrolusite*. At a depth of 4 or 5 feet from the surface it is mixed up with the matrix of the rock which is thin bedded quartzite. Deeper down the rock occurs without the ore, at least visibly. A pit south of the road exhibited under 4 feet of alluvium, 5 feet of quartzose-rock with *pyrolusite*.

Beyond Mungeli, traces of *pyrolusite* were observed at Deori (Deoree), close by the Umaria road in an insignificant outcrop of quartzites.

On the western side of the Lora syncline, the following localities may be noted commencing from the northern portion of the ground:—

9. Chhapra (Chhota), 5 miles north-east of Sihora.—In one of several pits sunk in a hillock a quarter of a mile south of the village, nodules of *pyrolusite* largely associated with *psilomelane* and *wad* and mixed up with blocks and fragments of quartzite, with or without veins and nests of the manganese-ores, were found to a depth of 10 feet from the surface. The quantity of *pyrolusite* here must be very small; and the nodules of it are never quite free from the quartzose rock.

10. Sihora.—At and about this place *pyrolusite* is present in fairly large quantity.

Just north of the encamping ground, a ridge of quartzose rocks runs along the strike north-eastward for a little over 2 miles. At the north-eastern extremity of this ridge traces of *pyrolusite* were found, but the pits dug here did not show any quantity of it. Further search here may prove more successful.

The ridge at places is formed of beds of hematite with interbedded laminated red jasper, passing below (vertically) and laterally (along strike) into quartzose rocks with impregnations of iron ore.

The ridge (which from the villages through which it runs may be called the

Mansukra-Silondi ridge) is scarped on the northern side, the strata dipping south-east. On this (the northern side) a pit exhibited shaly-quartzose strata underlying similar strata impregnated with iron-ore, these last passing under beds of hematite with interbedded jasper. The dip is about 40° south-east. The hematite, at the surface, is largely associated with manganese-ore, which I believe is *pyrolusite.* These mixed manganese-iron-ores are very plentiful in the portion of the ridge (1 mile in length) included within the limits of Mansukra, from the Mirzapur road to the streamlet forming the eastern boundary of that village. At spots the manganese predominates over the iron-ore, and sometimes, but rarely, the former is almost exclusively present. When the latter is the case, the *pyrolusite* is usually of small thickness (2 feet or less) and of small extent, passing vertically below and on all sides into iron-manganese ores, or quartzose rocks containing traces of these.

At one place, about 900 feet west of the boundary line between Mansukra and Silondi, the ore was found to be almost free from iron-ores and quartzose-matrix, and of exceptional thickness. Here almost a solid mass of good manganese-ore (*pyrolusite* intimately associated with a little hematite, and a little, but very little *psilomelane*) goes down to a depth of 11 feet in one of the pits. At this depth hematite with a trace of manganese-ore occurs. From the pits sunk here, the *pyrolusite* was found to cover an area of about 10,000 square feet. Taking its average thickness at 7 feet, there is present here some 70,000 cubic feet of manganese ore. Taking the specific gravity at 4·7, the quantity would amount to about 9,000 tons. From the entire hill some 12 or 13 thousand tons of the *pyrolusite* may be expected. From an assay made by Mr. E. J. Jones, of the Geological Survey, it was found to contain 81·24 per cent. of the available peroxide of manganese.

Inside the town of Sihora, nearly at its northern extremity, on a low ridge formed of cherty-looking quartzites, curiously intermingled with lateritic rock, rather good *pyrolusite* was found at one place. Traces of the ore were also found just west of the town by the road leading from it to Majhauli in an outcrop of the Gosalpur quartzites.

In the compound of the local court-house, where there is an outcrop of the Gosalpur quartzites, a pit showed, below 1 foot 8 inches of soil, a thickness of 12 feet of decomposed quartzose-rocks with nodules of manganese-ore, which appeared to be chiefly *wad.* The ore was mostly raised as a black powdery mass. Another pit, a little to the south, exhibited some 7 feet of quartzites, with veins and nests of *pyrolusite* (?).

11. Naigain.—South of Sihora, the quartzites are lost under alluvium. They re-appear at Naigain on the Hirun river, 2 miles north of Gosalpur. In one of the pits opened here, *pyrolusite* occurs as nodules in decomposed, yellowish quartzites down to a depth of 4 or 5 feet from surface. The quartzite at the surface contains veins and nests of the ore. But I do not expect there is any considerable quantity of it.

Proceeding southward traces of *pyrolusite* were found in the quartzites near Chandnota by the Hirun. The ore occurs in some quantity at,—

12. Dharampur.—A little over a mile west-north-west of this village, at the foot of a hill locally known as Changeli, there is an outcrop of apparently the Gosalpur quartzites, which at one place has the appearance of a breccia, consisting of frag-

ments of quartzite cemented by a matrix of *pyrolusite*. A trench dug close to it showed a good thickness of the ore, but seldom free from quartzite. The thickness was found to be 10 feet in one of the pits. The extent is some 30,000 square feet, if not more. Taking the average thickness at 6 feet, some 180,000 cubic feet of the ore may be expected from here. The ore is, however, as has just been observed, seldom entirely free from the quartzite. Making allowance for it, the quantity of dressed ore may be estimated at about 13,000 tons.

13. Dhangaon.—Nearly at the top of a low hill covered by thick scrub jungle, a mile north-east of this village, and close to the boundary line between it and Tala, an outcrop of quartzites similar to the one just mentioned led me to expect the ore; and it was found, though in thickness and extent it appeared to be poorer than the Changeli find.

14. Chindamani (Cheendamanee).—*Pyrolusite* occurs here, as at the last two places, in an outcrop of apparently the Gosalpur quartzites, about a quarter of a mile north-east of the village.

Traces of *pyrolusite* were also found at Kailwas (a mile north of Chindamani), one-third of a mile north of the village, in quartzites.

15. Nurgaon (nearly 4 miles east-north-east of Panagar).—A little over a quarter of a mile east of this village, in a *nala* at the foot of a ridge of Gosalpur quartzites, a small pocket-like deposit of *pyrolusite* was found amongst these. On the ridge, however, the quartzites were found impregnated with iron-ore alone.

16. Pararia (Purrurea).—A quarter of a mile east of this village (2 miles south-east of Panagar), there is a ridge of quartzites which have the appearance of being greatly crushed. At one place, at the south-eastern extremity of this ridge, and at its foot, a crust of well-crystallised *pyrolusite* was found on the surface of blackish quartzites. A pit here showed these rocks to be more or less impregnated with the ore. On the ridge, a little to the north-east of this pit, it also occurs, but with considerable admixture of the quartzite.

It is highly probable that the quartzite bands which stretch north-eastward from Nurgaon, and east-north-east from Pararia, if searched more closely than I was able to do, would yield some *pyrolusite;* but, from what I saw, I doubt if it is likely to be of good quality.

17. Kushi (Kasai) hill, 3 miles north-west of Sihora.—Manganese-ores are very plentiful in this hill. They appear, however, to be chiefly *psilomelane.*

At the south-eastern extremity of this hill, at its top, I observed some massive quartzites identical in appearance with the Gosalpur quartzites, and forming a syncline. Pits opened here exhibited some *pyrolusite* as nests in the quartzites.

Outside the Lora group, and nearer the base of the Bijawars of this area, traces of *pyrolusite* were found in the Majhauli-Bhitri group at the following places[1]:—

(A). CHHAPRÁ (*Bara*), 3 miles south of Sleemanabad.—On the southern slope of a hill, half a mile east of this village, at the boundary between it and Salaiá, I encountered a block of quartzose rock with nests of *pyrolusite*. The hill is covered by cherty rocks in boulder-like masses. Some pits were dug here, but no manganese-ore was found in any of these.

[1] For the places, see Map accompanying Mr. Mallet's paper on the Iron-ores of the Jabalpur district (Rec. Vol. XVI. Part 2).

(B). HARDUA KHURD (Hurdooa khoord), 12 miles west-south-west of the last place.—A mile north of this village at the south-western end of a ridge of cherty-looking reddish quartzites, traces of *pyrolusite* were observed.

(C). MURAITH (Mooreith), 7 miles north-west of Gosalpur.—Here traces of *pyrolusite* were found in some cherts occurring among chert-banded limestone

With regard to the Bijawar ground south-west of Jabalpur, I had time only to pay a hurried visit to Gangai, 4 miles south of Bhera Ghat. The Lora group occurs here, as has been mentioned by Mr. Hacket in his manuscript report. He notes the presence of quartz-rocks in the western portion of a hill near Dharampur, 3 miles south-west of Bhera Ghat. These rocks may be the representatives of the Gosalpur quartzites in this area. They certainly appear to run parallel to the Lora iron-ore-band, and may, I think, yield some *pyrolusite*.

A carefully selected average sample of the *pyrolusite* from Gosalpur yielded on analysis (Mallet "Man. of the Geol. of India," pt. IV, p. 58):—

Manganese	54·66
Oxygen	31·16
Iron Sesquioxide (with trace of alumina)	4·53
Baryta	3·56
Phosphoric acid	·28
Insoluble in hydrochloric acid	2·74
Combined water	2·41
Hygroscopic water	·28
	99·61

NOTE (A).

Notes on the Iron industry of the Lora hill area.

Nearly every village in the vicinity of the Lora range worked the manganiferous hematite ore at some time or other, as the slag mounds testify. South of the Hirun there were mines at Hirdenagar and Gosalpur. But north of the river, nearly all the furnaces appear to have been supplied by the Danwai mines situated at the boundary between Danwai and Gogra.

Last February, I saw four furnaces at work, two at Karaia and two at Hatwai—two small villages near Kaleri, about 9 miles north-east of Sihora. These four furnaces had been working since November. Two more furnaces were about to start work at Gogra when I visited that place (about the end of February).

The furnace, as usual, is of a most primitive type. It is 4 feet 6 inches in height from the hearth to the throat. The width is 1 foot 6 inches at the hearth, and 7 inches at the throat. The furnace is built of mud, with which some straw is mixed. The making-up of the furnace costs a rupee or so.

The bellows which supply the blast are about a foot and a half high when stretched. They are made up of goat's skins obtained from Jabalpur at a cost of R4 per pair; the making-up costs a rupee. A pair of bellows lasts one full season (November to May).

The entire cost of the furnace and bellows and other requisites amount probably to not more than R7.

The blast is supplied through a pair of clay tuyers, which are renewed every day.

The manganiferous hematite (which is the ore used) is procured from the Danwai mines. The ore has to travel 5 miles for the furnaces at Karaia, and 7 for those at Hatwai. It is carried on pack buffaloes to Karaia at a rate of 2 annas 9 pies for one

day's charge required for each furnace. This includes the cost of digging out and of dressing the ore (*i.e.*, breaking up the bigger lumps into small bits and roughly separating it from the rock matrix which is quartzite). The rate at Gogra, which is only a mile from the mines, is 2 annas per charge.

The fuel used is charcoal. The price paid for it is 8 annas for one day's consumption. This includes carriage. The quantity of charcoal consumed by a furnace in one day averages 4 maunds, so that it costs 2 annas per maund. This price appears to be abnormally low. I was told that it would take 12 men to work regularly for a month to prepare charcoal required for a month by one furnace; that is to say, the remuneration for these 12 men would be R15 per month, or R1-4 per head. There is no doubt that all the 12 men do not work steadily and systematically; and it is probable that 8 men would suffice if they work properly. Even then, however, the wage of a labourer per day would not be more than 1 anna, which is below the normal rate. The charcoal is procured at this low price by making advances to labourers during the rains.

The furnace is worked for 12 hours, from about 8 in the morning to late in the evening. Two men are required to work it, one at the bellows and the other to put in ore and fuel and let out the slag. Their wages vary from 2 to 3 annas each per day.

The furnace is first filled up with charcoal. When it gets well heated, ore is let down through a hole at the top about 7 inches square, one small basketful at a time weighing from 5 to 7 seers. Some 25 to 30 such basketsful (or $3\frac{1}{2}$ to $4\frac{1}{2}$ maunds) of ore are consumed by a furnace in one day.

The produce of the furnace is a steely iron, known as *kheri*,[1] which is used for tipping implements of various kinds such as hatchet-heads, ploughshares, &c. As suggested by Mr. Mallet, there can be no doubt that the quality of the iron is due to the presence of manganese in the ore.

The spongy mass of *kheri* which comes out of the furnace is partially mixed up with slags. When cooled, it is beaten down with a heavy hammer, and broken into small blocks and fragments, the slags separating out in the process. The daily outturn of a furnace averages 24 seers of *cleaned kheri*.

The selling price varies. At the furnace it averages R10 per *gond* (= 24 *paseris*, or 3 maunds and 24 seers), or about 14 seers per rupee. At Sihora the price, according to my information, was 8 seers per rupee.

The working expenses of a furnace per month may be estimated as follows:—

	R	*a.*
Digging, dressing and carriage of ore at 2 annas per day (the Gogra rate)	3	12
Charcoal at 8 annas per day	15	0
Two bellowsmen (6 annas per day)	11	4
Duty on wood burned for charcoal	4	0
Royalty on ores	1	6
On account of bellows, &c.	1	0
Total	36	6

The monthly outturn averages 30 × 24 seers = 18 maunds. At R10 per *gond* of $3\frac{1}{2}$ maunds, the value of the outturn would be about R51-6. This leaves a fair margin for profit.

If the Umaria coal be found suitable, there is very good prospect for a steel manufactory on a large scale in the Lora hill area; and Khatola, where there is a railway station, appears to me to be best suited for the purpose. There is very rich manganiferous iron-ore close by (see p. 75); and the Hirun, probably the largest river in the northern portion of the Jabalpur district, flows past it.

[1] According to Mr. McMinn (*Central Indian News*, September, 1886), *Kheri* contains "80 per cent. of steel worth £45 per ton. It costs now in Jabalpur under £6 per ton."

NOTE (B).

The following statistics compiled from Phillips' "Treatise on Ore Deposit" and R. Hunt's "British Mining," may be found useful in forming an estimate of the value of the Jabalpur ores. The Manganese ores include *pyrolusite, manganite, psilomelane,* &c. :—

YEAR.	Quantity of manganese-ores.	Value.
I.—THE UNITED KINGDOM—	Tons.	£
1. Production of the mines in Cornwall, Devonshire, &c.		
1880	2,839	5,601
1881	2,884	6,441
1882	1,548	3,907
2. Imports.		
1880	16,085	67,070
1881	18,748	71,140
1882	29,760	102,267
-FRANCE, 1880	9,652	21,309
THE GERMAN EMPIRE, 1881	13,642	23,534
ITALY, 1880.	6,505	8,575
—SPAIN, 1882	5,668	9,115
VI.—THE UNITED STATES, 1882.	3,500	10,500

"The Carboniferous Glacial Period," *by* Oberbergrath Prof. DR. W. WAAGEN.[1] *Translated by* R. BRUCE FOOTE, F.G.S., *Superintendent, Geological Survey of India.* (With one plate.)

Since the time when Agassiz and others entered upon a close study of glaciers, and it became practicable to recognize deposits formed by ice, even where the forming agency, the ice itself, had long disappeared, perfectly new vistas have opened to geological enquiry, and it has become possible to look back into the climatic conditions of periods which had long preceded historical tradition, and which till then had been regarded as separated by a great gulf from the present development of things. Studies in this direction, however, extended in the first place only to the glacial formations of the quarternary period, partly because the ice-formed deposits

[1] Jahrbuch der K. K. Geol. Reichsanstalt, 1887, 37, Band. 2, Heft. (W. Waagen).

belonging to this period are generally rather superficial in position, cover a comparatively large area, and play thus a more or less important part in the geological composition of many regions; partly also because, for obvious reasons, organic remains are pretty generally absent from glacial formations, and thus the age of such formations as do not belong to the quarternary period is generally extremely difficult to determine.

In spite of this, many voices have already been raised of those who believed they could demonstrate the action of ice in formations older than the quarternary; and there is hardly one of the greater epochs later than the Cambrian in which such formations have not been indicated: indeed, James Croll held that he could prove that each of the greater epochs in the history of the earth must consist of a series of glacial and interglacial periods. In this he deals very liberally with millions of years.

These voices have, however, hitherto died away with rather slight notice, because the whole body of geological facts would not fit in kindly with the theory, and because the facts, and specially those observed in the British islands, appeared on the one hand always as local phenomena only, while on the other hand, an unquestionably glacial character of these formations could not be absolutely proved. As time went on facts increased and proofs accumulated: and to-day it is hardly feasible any longer to wrap oneself in dissentient silence in opposition to the question whether glacial appearances are not traceable in prequarternary times; for the fact of the existence of glacial deposits is pretty generally admitted, although one could not begin to do much in general with this fact, a close determination of the age of these glacial formations being subject to very special difficulties.

It is one of the incontestably great merits of the Geological Survey of India to have advanced this "Glacial" question into the foreground, and to have published numerous facts tending towards its solution. The first case which was established by these studies, and which was one of great weight, was the fact that it appeared thus to be proven that the glacial beds in formations older than the quarternary are not merely local phenomena such as are found only in certain localities in England, but are really widespread and extending over great parts of the earth.

The oldest observations of the kind concerned India; where, in the year 1856, the so-called Talchir conglomerates were discovered, which were at the time pronounced by W. T. Blanford to be glacial. The definitive proofs of this were, however, only obtained in 1872 by Thomas Oldham and Fedden, who jointly excavated in the valley of the Godavari numerous scratched blocks of these beds, and also found the underlying formation, a hard Vindhyan limestone, to be scored with innumerable deep parallel scratches. A large granite block then found is exhibited in the Indian Museum in Calcutta, and forbids any doubt as to its having been tooled by ice.[1]

Another region in which conglomerates of peculiar character had long been known is South Africa. This formation was for a long while held to be of volcanic origin, till at last Sutherland[2] recognized the glacial origin of these block deposits

[1] Mem. Geol. Surv. Ind., Vol. IX, Part 2, p. 30. (Mr. Fedden made the original find. W. K.—*Ed.*)

[2] Quart. Journ. Geol. Soc. Lond., Vol. XXVI, p. 514.

also. Our countryman Griesbach, who knew these deposits from personal inspection in South Africa, was, when he came to India, surprised at the similarity which the Indian Talchir conglomerates show to the South African conglomerates, and did not hesitate to bring the two formations into correlation.

A third region in which glacial deposits in older formations were indicated was Australia. Before all others, it was the so-called Bacchus-marsh sandstone that was recognized as glacial, while the Hawksbury beds also appeared to have come into existence under glacial influences.

In all these three regions the glacial deposits appear in connection with coal seams, or sandstones containing a rich flora. This flora was by the majority of, and the best, palæophytologists regarded as Mesozoic; but the stratigraphical relations in India, and yet more especially in Australia, distinctly demanded that these formations should be reckoned in the Palæozoic rock series.

An irresolvable contradiction was thus created, which called forth a division of minds. Endless controversies were held in favour of one or other view: and the importance of the occurrence of glacial formations in these beds receded into the back ground, just because the exact age of the whole series of beds could not be determined with certainty. I will now endeavour to give a picture of the relative conditions for German readers, but in so doing cannot avoid repeating much that has already been variously discussed in German periodicals.

I.—INDIA.

The fundamental studies of these formations were published in 1856 by W. T. Blanford; and later on the whole series of beds received from H. B. Medlicott the name of "The Gondwana System."

Comprehensive data on this subject were given by W. T. Blanford in the *Manual of the Geology of India*, and more lately in his Address to the British Association at Montreal. His brother, H. F. Blanford, also gave a very good review of the subject, as then known, in his essay "*On the* Age *and* Correlations *of the* Plant-bearing Series *of* India, *and the former* Existence *of an* Indo-oceanic Continent" (Quart. Jour. Geol. Soc. London, Vol. XXXI, p. 519, 1875). The organic remains were worked out by Feistmantel.

It is difficult to treat the subject afresh since it has been so largely and so well written on. In particular it appears to me hardly possible to excel, or even to attain to, the masterly representation of the conditions given by W. T. Blanford in his Montreal Address: it will therefore be the wisest plan to let the first founder and zealous promoter of the whole question also speak on it in this place. I shall content myself therefore by giving here (in translation) the respective passages in Blanford's Address, and only making such additions to it as appear desirable for the benefit of German readers.

"*Gondwana System of India.*—In the peninsula of India there is a remarkable deficiency of marine formations. Except in the neighbourhood of the coast or of the Indus Valley there is, with one exception (some cretaceous rocks in the Nerbudda Valley), not a single marine deposit known south of the great Gangetic plain. But in Bengal and Central India, over extensive tracts of country, a great sequence of fresh-water beds, probably of fluviatile origin, is found, to which the name of

Gondwana system has been applied. The uppermost beds of this system, in Cutch to the westward, and near the mouth of the Godavari to the eastward, are interstratified with marine beds containing fossils of the highest Jurassic (Portlandian and Tithonian) types.[1]

"The Gondwana system is a true system in the sense that all the series comprised are closely connected with each other by both biological and physical characters, but it represents in all probability a much longer period of geological time than do any of the typical European systems. The highest members, as already stated, are interstratified with marine beds containing uppermost Jurassic fossils. The age of the lowest members is less definitely determined, and has been by different writers classed in various series from middle carboniferous to middle Jurassic. The Gondwana beds from top to bottom are of unusual interest on account of the extraordinary conflict of palæontological evidence that they present.

"The subdivisions of the Gondwana system are numerous, and in the upper portions especially the series and stages are different in almost every tract where the rocks are found. The following are the sub-divisions of most importance on account of their fauna and flora, or of their geological relations:—

Upper Gondwana ...	Cutch and Jabalpur.	
	Kota Maleri.	
	Rájmahál.	
Lower Gondwana ...	Panchet.	
	Damuda ...	Ranigunj and Kámthi.
		Barákár.
	Karharbári.	
	Tálchir.	

"The upper Gondwanas, where best developed, attain a thickness of 11,000 feet and the lower of 13,000 feet.

"The Talchir and Barakar sub-divisions are far more generally present than any of the others.

"*Tálchir.*—The Tálchir beds consist of fine silty shales and fine soft sandstone. Very few fossils have been found in them, and these few recur almost without exception in the Karharbári stage. The Talchirs are principally remarkable for the frequent occurrence of large boulders, chiefly of metamorphic rocks. These boulders are sometimes of great size, 6 feet or more across, 3 to 4 feet being a common diameter; all are rounded, and they are generally embedded in fine silt."

These boulder beds are very widely distributed in Bengal and Central India, and boulders whose surfaces are marked with numerous parallel scratches are by no means uncommon. They form generally the base of the whole coal and plant-bearing series, and rest very often unconformably on older rocks. It has already been mentioned that when the basement is freshly exposed, the surface is scored with distinct parallel striæ. The thickness is often very great, but naturally changes within short distances. The glacial origin of these boulder deposits is clear beyond all cavil.

Griesbach[2] has given a very instructive chromo-lithographed sketch of such

[1] This and the following quoted passages are all from Mr. Blanford's address as President of the Geological Section of the British Association, at Montreal, 1884: also published in Records, G. S. I., XVIII, p. 32 *et. seq.*—W. K.

[2] Mem. Geol. Surv. Ind., 1880, Vol. XV, pt. 2, pl. 2.

a bed, which shows most convincingly the irregular distribution of the boulders in the fine greyish-green sandy clay. The soft sandstone and shales occur generally only above the boulder clay. A few plant remains occur in the shales, and from among them Feistmantel determined the following species :—

Schizoneura, sp.
Gangamopteris cyclopteroides, Fstm.
„ angustifolia, McCoy.
Glossopteris, sp.
Næggerathiopsis hislopi, Bunb., sp.

Of these *Gangamopteris cyclopteroides* is the predominant form, and *G. angustifolia* is identical with a form that was originally described from the Bacchus-marsh sandstone. This Australian formation also shows similar characters.

"*Karharbári.*—The Karharbári beds are found in but few localities." They stand in the closest relation to the Tálchir beds, and can hardly be regarded as a separate division. Here and there they contain coal-seams, and are then often rather rich in plant remains.

Up to the present Feistmantel has described the following species from these beds :—

Schizoneura cf. meriani, Schimp.
Vertebraria indica, Royle.
Neuropteris valida, Fstm.
Gangamopteris cyclopteroides. Fstm. in many varieties.
„ buriadica, Fstm.
„ major, Fstm.
„ angustifolia, McCoy.
Glossopteris communis, Fstm.
„ decipiens, Fstm.
Sagenopteris stoliczkana, Fstm.
Glossozamites stoliczkanus, Fstm.
Næggerathiopsis hislopi, Bunb., sp.
Euryphyllum whittianum, Fstm.
Voltzia heterophylla, Brogn.
Albertia, sp.
Samaropsis cf. parvula, Heer.
Carpolithes milleri, Fstm.

"The most abundant form is a *Gangamopteris.* The *Voltzia* (*V. heterophylla*) is a characteristic Lower Triassic (Bunter) form in Europe. The *Neuropteris* and *Albertia* are also nearly related to the Lower Triassic forms. The species of *Gangamopteris, Glossopteris, Vertebraria* and *Næggerathiopsis* are allied to forms found in Australian strata." I myself had occasion to study the Karharbári beds more closely during an excursion which I made in the summer of 1871 with Dr. Stoliczka. Mr. Heine, a German, was then manager of the collieries at Karharbári. He had just then bared the coal seams in a couple of open workings, and invited us to inspect these workings. We found two seams exposed to daylight (at small depths) in terrace-like steps by the clearing away of the overlying sandstone mass, so that only a thin layer of shale covered the coal itself. The exposed surface measured at the lowest estimate many square metres, and was covered with well-preserved plant remains,—a real joy to the eye of a palæontologist. Unluckily the harvest was not so great as we had expected. It was the hot season; and the shales had been exposed for

several days to the glowing sun and to the furnace blasts of the hot winds, and the rock was in consequence so cracked that it crumbled away under the lightest ouch of chisel or hammer. If Mr. Heine had not previously preserved specimens for us, we must have departed empty-handed. The specimens then procured formed the chief basis for Feistmantel's descriptions. Only few geological observations could then be made because of the terrible heat. The beds are all nearly horizon tal, but their relations to the not distant beds of the Damuda coal-basin could not be accurately observed because vast tropical forests cover a great part of that region.

"*Damuda.*—The Damuda series consists of sandstones and shales with coal beds : the floras of the different sub-divisions present but few differences," * * * Feistmantel has described the following species out of the Damuda series :—

Schizoneura gondwanensis, Fstm.
Phyllotheca Indica, Bunb.
" *robusta, Fstm.*
Trizygia speciosa, Royle.
Vertebraria indica, Royle.
Cyathea cf. tchihatcheffi, Schmalh.
Sphenopteris polymorpha, Fstm.
Dicksonia hughesi, Fstm.
Alethopteris whitbyensis, Goepp.
" *lindleyana, Royle.*
" *phegopteroides, Fstm.*
Pecopteris affinis, McCl.
Merianopteris major, Fstm.
Macrotæniopteris danæoides, Royle.
" *feddeni, Fstm.*
Palæovittaria kurzi, Fstm.
Angiopteridium cf. m'clellandi, Oldh.
" *infractum, Fstm.*
Glossopteris communis, Fstm.
" *intermittens, Fstm.*
" *stricta, Bunb.*
" *musafolia, Bunb.*
" *indica, Schimp.*
" *browniana, Bgt.*
" *intermedia, Fstm.*
" *retifera, Fstm.*
" *conspicua, Fstm.*
" *ingens, Fstm.*
" *divergens, Fstm.*
" *damudica, Fstm.*
" *angustifolia, Bgt.*
" *leptoneura, Bunb.*
" *formosa, Fstm.*
" *orbicularis, Fstm.*
Gangamopteris anthrophyoides, Fstm.
" *whittiana, Fstm.*
" *hughesi, Fstm.*
" *cyclopteroides, Fstm.*
Belemnopteris wood-masoni, Fstm.
Anthrophyopsis, sp.
Dictyopteridium, sp.

Sagenopteris logifolia, Fstm.
" polyphylla, Fstm.
Actinopteris bengalensis, Fstm.
Pterophyllum burdwanense, M'Cl., sp.
Anomozamites, sp.
Næggerathiopsis hislopi, Fstm.
Rhipidopsis densinervis, Fstm.
Voltzia heterophylla, Brgt.
Samaropsis cf. parvula, Heer.

Besides these a few animal remains were found, *viz.*—

Estheria mangaliensis, Jones.
Brachyops laticeps, Owen.
Gondwanosaurus bijorensis, Lyd.

Of these remains there is nothing more to be said than that *Brachyops* is more or less nearly related, while *Gondwanosaurus* approaches very closely to *Archegosaurus*.

"The most abundant of the above-named fossils are *Glossopteris* and *Vertebraria*. With the exception of *Næggerathiopsis*, all the cycads and conifers are of excessive rarity. More than one-half of the species known are ferns with simple undivided fronds and anastomosing venation."

"For many years European palæontologists generally classed this flora as Jurassic. This was the view accepted by De Zigno and Schimper, and, though with more hesitation, by Bunbury. The species of *Phyllotheca*, *Alethopteris* (or *Pecopteris*), and *Glossopteris* (allied to *Sagenopteris*) were considered to exhibit marked Jurassic affinities. It was generally admitted that the Damuda flora resembles that of the Australian coal-measures * * * * more than it does that from any known European formation; but the Australian plants were also classed as Jurassic. There is no reason for supposing that the more recent discoveries of Damuda plants would have modified this view; the identification of such forms as true *Sagenopteris* and the cycads *Pterophyllum* and *Anomozamites* would assuredly have been held to confirm the Jurassic age of the beds. So far as European fossil plants are concerned, the Damuda flora resembles that of the Middle or Lower Jurassics more than any other.

"One form, it is true, the *Schizoneura*, is closely allied to *S. paradoxa* from the Bunter or lower Trias of Europe. Other plants have Rhætic affinities. But the connections with the Triassic flora do not seem nearly equal to those shown with Jurassic plants, and the reason that the Damuda flora has been classed as probably Triassic must be sought in the impossibility of considering it newer, if the next overlying stage is classed as Upper Trias or Rhætic, and in the close affinity with the underlying Karharbári beds, which contain several Lower Triassic types.

"*Panchet.*—The uppermost series of the Lower Gondwanas consists chiefly of sandstone, and fossils are rare. The most interesting are remains of *Reptilia* and *Amphibia*." The following is a list of the faunna and flora :—

Epicampodon indicus, Huxley, sp.
Dicynodon orientalis, Huxl.
Pachygonia incurvata, Huxl.
Gonioglyptus longirostris, Huxl.
" huxleyi, Lyd.

Glyptognathus fragilis, Lyd.
Estheria, sp.
Schizoneura gondwanensis, Fstm.
Vertebraria indica, Royle.
Pecopteris concinna, Presl.
Cyclopteris pachyrrhachis, Goepp.
Thinnfeldia cf. *odontopteroides*, Morr., sp.
Oleandridium cf. *stenoneuron*, Schenk.
Glossopteris communis, Fstm.
 " *indica*, Schimp.
 " *damudica*, Fstm.
 " *angustifolia*, Bgt.
Samaropsis cf. *parvula*, Heer.

The *Schizoneura*, the *Vertebraria* and the various species of *Glossopteris* are identical with those found in the Damuda beds. Besides them are several species identical with those of the Rhætic beds of Europe, and two others have their nearest relatives in these beds, and thus perhaps the whole flora of the Panchets may be regarded as Rhætic, or at least as Triassic.

" All the genera of *Labyrinthodonts* named are peculiar, their nearest European allies are chiefly Triassic. *Dicynodontia* are only known with certainty from India and South Africa, but some forms believed to be nearly allied have been described from the Ural Mountains. These fossils were obtained from rocks now referred to the Permian.

" *Upper Gondwanas.*—The different series of the lower Gondwanas are found in the same area resting one upon the other, so that the sequence is determined geologically. This is not the case with the upper Gondwana groups; their most fossiliferous representatives are found in different parts of the country, and the relations to each other are mainly inferred from palæobotanical data. Although, therefore, it is probable that the Rájmahâls are older than the Cutch and Jabalpur beds, and that the Kota-Maleri strata are of intermediate age, it is quite possible that two or more of these series may have been contemporaneously formed in regions with a different flora.

" *Rájmahál.*—The comparatively rich flora of the lowest upper Gondwana series is contained in beds interstratified with basaltic lava-flows of the fissure-eruption type." The following are the genera of plants found :—

Equisetum rajmahalense, Schimp.
Gleichenia bindrabunensis, Schimp.
Danæopsis rajmahalensis, Fstm.
Dicksonia bindrabunensis, Fstm.
Hymenophyllites bunburyanus, Oldh.
Pecopteris lobata, Oldh.
Sphenopteris hislopi, Oldh.
 " *membranosa*, Fstm.
Cyclopteris oldhami, Fstm.
Thinnfeldia indica, Fstm.
Asplenites macrocarpus, Oldh.
Macrotæniopteris crassinervis, Fstm.
 " *lata*, Oldh.
 " *morrisi*, Oldh.
 " *ovata*, Schimp.

Angiopteridium spathulatum, M'Cl., sp.
" *m'clellandi*, Oldh., sp.
" *ensis*, Oldh., sp.
Rhizomopteris balli, Fstm.
Lycopodites gracilis, Fstm.
Pterophyllum carterianum, Oldh.
" *crassum*, Morr.
" *distans*, Morr.
" *kingianum*, Fstm.
" *medlicottianum*, Oldh.
" *propinquum* Goepp.
" *rajmahalense*, Morr.
Anomozamites fissus, Fstm.
" *morrisianus*, Oldh., sp.
" *princeps*, Oldh., sp.
Zamites proximus, Fstm.
Ptilophyllum tenerrimum, Fstm.
Otozamites abbreviatus, Fstm.
" *bengalensis*, Schimp.
" *oldhami*, Fstm.
Dictyozamites indicus, Fstm.
Cycadites confertus, Oldh.
" *rajmaholensis* Oldh.
Williamsonia cf. *gigas*, Carr.
" *microps*, Fstm.
Cycardinocarpus rajmahalensis, Fstm.
Palissya conferta, Oldh., sp.
" *indica*, Oldh., sp.
Cheirolepis cf. *münsteri*, Schimp.
Araucarites macropterus, Fstm.
Cunninghamites, sp.
Echinostrobus rajmahalensis, Fstm.

"The marked change from the Lower Gondwana floras is visible at a glance; not a single species is common to both, most of the genera are distinct, and the difference is even greater when the commonest plants are compared. In the Lower Gondwanas the prevalent forms are *Equisetaceæ* and ferns of the *Glossopteris* type, whilst in the Rájmahál flora cycads are by far more abundant than any other plants. The whole assemblage, moreover, is more nearly allied than are any of those in the Lower Gondwana beds to European mesozoic floras.

"Of the Rájmahál plants about fifteen are allied to Rhætic European forms, three to Liassic or lower Jurassic (two of these having also Rhætic affinities), and six to Middle Jurassic (two having Rhætic relations as well). The flora must therefore, as a whole on purely palæontological grounds, be classed as Rhætic."

Although Professor Feistmantel wishes to have the Rájmahál beds also regarded as Liassic, he cannot adduce any cogent reasons for it; though it is not meant to imply hereby that these beds might not in part be contemporaneous with liassic formations.

"*Kota Maleri*.—The deposits belonging to this series are found in the Godavari valley at a considerable distance from the Rájmahál hills in Bengal, the locality for the Rájmahál flora. Both Rájmahál and Kota-Maleri beds overlie rocks of the Damuda series. It is not quite clear whether the Kota beds, which contain fish, insects, and crustaceans, and the Maleri beds, in which remains of fish, reptiles, and plants are found, are interstratified, or whether the Kota beds overlie those of

Maleri. That the two are closely connected is generally admitted." From the Maleri beds the following remains have been recorded :—

Hyperodapedon huxleyi, Lyd.
Parasuchus hislopi, Lyd.
Pachygonia cf. incurvata, Huxl.
Scutæ of undetermined Labyrinthodonta.
Ceratodus virapa, Oldh.
,, *hunterianus, Oldh.*
,, *hislopianus, Oldh.*
Lepidotus pachylepis, Eg.
,, *calcaratus, Eg.*
,, *deccanensis, Sykes, Eg.*
,, *longiceps, Eg.*
,, *breviceps, Eg.*
Tetragonolepis oldhami, Eg.
,, *analis, Eg.*
,, *urgosus, Eg.*
Dapedius egertoni, Sykes.
Estheria kotahensis, Jones.
Candona kotahensis, Jones.
Angiopteridium spathulatum, M'Cl.
Ptilophyllum acutifolium, Morr.
Cycadites, sp.
Palissya conferta, Oldh.
,, *jabalpurensis, Fstm.*
,, *indica, Oldh.*
Chirolepis, sp.
Araucarites cutchensis, Fstm.

In South Rewa remains of *Belodon* and (?) *Thecodontosaurus* were found in beds of probably similar age, while from Denwa a *Mastodonsaurus* has been described.

"The fish are Liassic forms." The reptilia of the Maleri beds are on the other hand triassic. "*Ceratodus* is chiefly triassic." But it occurs also in the Permian and Jurassic. The plants show relations with both the Rájmahál and Jabalpur floras; and as the palæontological relations to beds in the same country are considered far higher in importance than those to deposits in distant regions, the Kota Maleri beds are classed as intermediate between the Rájmahál and Jabalpur epochs.

"*Cutch* and *Jabalpur.*—The Jabalpur beds are found in Central India to the south of the Nerbudda valley, and form the highest true Gondwana beds. The Cutch beds, as already mentioned, are found interstratified with marine deposits of uppermost Jurassic age far to the westward, a little east of the mouths of the river Indus. The similarity of the plant remains in the two series has caused them to be classed together, but it is not certain that they are really of contemporaneous origin." Similar beds have also been found in South India on the east coast near the mouth of the Godavari, but their flora is already somewhat differentiated.

The following species have been determined up to date out of the Jabalpur beds :—

Sphenopteris cf. arguta, L. and H.
Dicksonia, sp.

Alethopteris lobifolia, Schimp.
„ medlicottiana Oldh.
„ whitbyensis, Göpp.
Macrotæniopteris, sp.
Glossopteris cf. communis.
Sagenopteris, sp.
Podosamites lanceolatus, L. and H.
„ spathulatus, Fstm.
*„ *hacketi, Fstm.*
Otosamites hislopi, Oldh.
„ gracilis, Schimp.
„ distans, Fstm.
„ angustatus, Fstm.
Ptilophylium acutifolium.
„ cutchense, Morr.
Pterophyllum nerbuddiacum, Fstm.
Williamsonia cf. gigas, Corr.
Cycadites cf. graminens, Heer.
Palissya indica, Oldh.
„ jabalpurensis, Fstm.
Araucarites cutchensis, Fstm.
Brachyphyllum mamillare, L. and H.
Echinostrobus expansus, Schimp.
Taxites tenerrimus, Fstm.
Ginko lobata, Fstm.
Czekanowskia, sp.
Phœnicopsis, sp.

Of these plants six are identical with species from the lower Oolite of England, and a few others are nearly related to the same. The occurrence of *Glossopteris* and *Sagenopteris* gives a somewhat archaic aspect to the whole flora. Besides the above are four species, which are identical with four others from the Rájmahál beds.

The following fossil plants were procured in the peninsula of Cutch:—

Chondrites dichotomus, Morr.
Oléandridium vittatum, Brgt.
Tæniopteris densinervis, Fstm.
* *Alethopteris whitbyensis, Brgt.*
Pecopteris tenera, Fstm.
Pachypteris specifica, Fstm.
„ brevipinnata, Fstm.
Actinopteris, sp.
* *Ptilophylium cutchense, Morr.*
* *„ acutifolium, Morr.*
„ brachyphyllum, Fstm.
Otosamites contiguus, Fstm.
„ imbricatus, Fstm.
„ cf. goldiæi, Brgt.
Cycadites cutchensis, Fstm.
Williamsonia blanfordi, Fstm.
Cycadolepis pilosa, Fstm.
Palissya boojoorensis, Fstm.
Pachyphyllum divaricatum, Bunb.
Echinostrobus expansus, Schimp.

The species marked with asterisks are identical with species from the Jabalpur beds, and it is possible also that one of the unnamed species of *Palissya* may also have to be regarded as identical. Seven are, according to Feistmantel, identical with species from the Lower Oolite of Yorkshire, and further, three very closely related; but probably the identity of only the four is really established.

The plant-bearing beds are in their lower parts interbedded with marine deposits, which represent the upper division of a long series of Jurassic beds, within the limits of which all the zones of the Kelloway, Oxford, and Kimmeridge groups are represented.

The upper bed in particular has yielded the following cephalopoda:—

Haploceras cf. tomephorum, *Zitt.*
Aspidoceras wynnei, *Waagen.*
Perisphinctes cf. suprajurensis, *Orb.*
" *bleicheri*, *Lor.*
" *occultefurcatus*, *Waagen.*
" *eudichotomus*, *Zitt.*

All these are Portland-Tithonian types. The plant-bearing beds are overlaid by Aptian deposits.

This concludes the series of the several divisions of the Gondwana system. To enter further into the controversies as to the real age of these uppermost plant beds would take me beyond the scope of the present work.

The final result of the whole presentment appears to be that there exists in India a great rock system which includes at its base glacial deposits, and which, according to the fossil plants it contains, has been regarded as belonging to the Mesozoic era. But doubts as to this conclusion were advanced because it appeared probable on geological grounds, that the lower divisions of the system were of greater antiquity. W. T. Blanford has sought to prove by arduous and spirited deductions that the Tálchirs and Damudas answer to the Permian of Europe, and in so doing came very near to the truth, but he had no positive proofs; and thus the palæoplytologists were still at liberty to abide by their views, and to regard the type of the floras as determinant of the age of the formations.

Blanford had in his deductions already partially leant upon the presence of the glacial formations.

II.—SOUTH AFRICA.

In the matter of geological details in Africa we are unfortunately much less well-informed than could be desired, or than we are with regard to India. Roughly sketched, the geological structure of South Africa may be represented as a vast sandstone region occupying the entire centre, the margins of which are framed by a broad belt of older formations, crystalline rocks, old slates, and Devonian beds. On the outside edge along the coast small tracts of the central sandstone formation re-appear in isolated patches; here, however, the sandstones are interbedded with marine formations, which are entirely wanting in the central area.

The whole structure itself reminds one strongly of the conditions pertaining in India; and the resemblance becomes yet more striking the more one goes into detail.

It is the central sandstone formation, the so-called Karoo formation, which is

especially interesting. This formation spreads itself throughout the north part of the Cape Colony, the Orange Free State, Natal, the Transvaal, and the deserts lying further westward, and shows a series of sandstones and shales (interrupted here and there by eruptive rocks), which attains a maximum thickness of about 5,000 feet. The basis of the whole system is a rather varied one, as it for the most part rests uncomformably on the older rocks.

Most frequently the basis consists of the so-called Table Mountain sandstones, whose age has been much disputed. They are generally regarded as Devonian, but in an essay which has just appeared, E. Cohen[1] has shown that they should preferably be reckoned to the Carboniferous system. They rest partly in unconformity on clay-slates of probably Silurian age, and partly conformably on the richly fossiliferous Devonian grey-wackes of the Bokkeveld. Other whitish or yellowish sandstones which appear on the Witteberg and Zuurberg, as also near Graham's Town, Winterhock[2] and other places, have yielded remains of *Lepidodendron*. At Tulbagh, in the Cape Colony, these beds contain coal, in which remains of *Calamites*, *Equisetum* and *Lepidodendron* are found.[3]

Overlying these formations unconformably comes the Karoo formation, which often rests directly on the Devonian grey-wackes.

The Karoo formation is reducible to a series of sub-formations, which may be represented as follows according to Wyley's full classification :—

	Stormberg beds	1,800′ thick.
	Beaufort beds	1,700′ „
	Koonap beds	1,500′ „
Ecca beds	Upper Ecca shales	1,200′ „
	Ecca conglomerate	500′—800′ thick.
	Lower Ecca shales	of no great thickness.

The lowest beds of the lower Ecca shales are said to be strongly contorted equally with the sandstones which are connected with them. They occur at the same places with the Carboniferous sandstones above referred to (Witteberg, Zuurberg, &c.) and are reported fossiliferous.

As all the other beds, both over and underlying, are nearly absolutely horizontal and undisturbed, the contorted character of these shales is remarkable. They occur, however, but in few places.

In general, the older deposits are overlaid by the *Ecca conglomerate*, a most remarkable rock, which for many years was regarded as eruptive and called a "trap breccia." Dr. Sutherland was the first who recognized the action of ice in the formation of these beds, but at the time his views met with much objection.[4]

Dr. Sutherland describes the deposit as composed of grey-blue clayey material, in which fragments of granite, gneiss, greenstone, and clay slate are imbedded. These fragments are of very various sizes from little grains of sand to huge blocks, 6 feet in diameter and weighing from 6 to 10 tons. These blocks are generally smoothed, as if they had been to a certain extent ground down in a clayey sediment, but they are not rounded like blocks which have been exposed to surf-

[1] E. Cohen, Neues Jahrb. f. Min. Geol. u. Pal. V. Beil-Band, 1887, p. 195.
[2] Wyley, Quart. Jour. Geol. Soc. Lond., XXIII, 1867, p. 173.
[3] Griesbach., Ibid, XXVII, 1881, p. 57.
[4] Quart Jour. Geol. Soc. Lond., 1870, Vol. XXVI, p. 514.

action. The fracture of the clayey matrix is not conchoidal; and, in general, the rock shows a certain tendency to obscure wavy bedding. In places the beds show distinct ripple marks. The thickness of this formation is very various, but in some places it attains as much as 1,200 feet.

These conglomerates rest, as a rule, unconformably on the Table Mountain sandstones, and at the surfaces of contact the sandstones are generally marked with deep grooves and scratchings "as if a heavy semi-plastic substance with included hard and angular fragments had moved across it;" a very drastic description of the effects of a moving ice-mass!

In an upward direction the conglomerates pass quite gradually into the next overlying group of beds.

Upper Ecca Shales.—These are generally dark-grey shales of very considerable thickness with but few intercalated sandstones. Locally they contain coal seams, and plant remains are reported not unfrequent, but up to the present only the genus *Glossopteris* has been cited.

Koonap beds.—Brown sandstone and shales, which latter, however, often show a greenish tint. Plant remains are common, particularly in the upper beds, but the plants have not yet been described.

Beaufort beds.—Dark red greenish or grey shales, with comparatively few sandstone deposits, but with all the more numerous reptile-remains. Fish teeth and plant impressions also occur there. The Karoo plant-remains, described by Tate, are said to have come out of these beds, but might just as well have been derived from the Koonap beds. The bed is unfortunately not sufficiently well known. The following species have been described:—

Glossopteris browniana, Bgt.
" *sutherlandi, Tate.*
" *(Dictyopteris?) simplex, Tate.*
" *(Rubidgea) mackayi, Tate.*
Phyllotheca sp.

At the first glance it is clear that these plants have a great resemblance to those of the Damuda beds. On the other hand, they are also nearly allied to similar species in Australia as will be clearly shown further on.

The fauna of the Beaufort beds is much richer than the flora. Up to the present only vertebrate remains have been found, a complete enumeration of which is given in Owen's Catalogue of the Fossil Reptilia of South Africa, contained in the British Museum.

Three groups in particular are represented—the Dicynodonta, the Theriodonta, and the Dinosauria. We have already seen that Dicynodonta occur in the Indian Panchet beds.

The Stormberg beds.—Thick sandstones of white or light red colour, with subordinate beds of shale and coal seams. Of plant-remains the following species have been described up to the present:—

Pecopteris (thinnfeldiā), Bgt.
" *sutherlandi, Tate.*
Cyclopteris cuneata.
Tæniopteris daintreei.[1]

[1] Dunn, Report on the Stormberg Coalfield. Geol. Mag., 1879, p. 552.

All these are species which occur equally in the uppermost plant-bearing beds of Australia. Of animal remains the skull of a mammal has *imprimis* been described and received the name of *Tritylodon triglyphus*.[1]

Neumayr has shown that this specimen is remarkably near in its alliance to the genus *Triglyphus* of Fraas from the Rhætic bone bed of Würtemberg, and might possibly be, by some, regarded as generically identical.

If all the relations of the Stormberg beds to the extra-African formations be considered, it would appear that of the Indian rocks the Rájmahál and Jabalpur formations should first be reckoned as their equivalents.

The Uitenhage group.—In the interior, the Karoo system terminates with the Stormberg beds; but along the coast, from the southernmost point up to the neighbourhood of Natal and the Tugela river, appear marine beds alternating with plant-bearing beds, which are assigned partly to the Jurassic, partly to the middle and upper Cretaceous periods. The relations of these deposits to the Karoo system are obscure, and have up to the present not been worked out with sufficient care. But nevertheless the beds are of great interest. The cretaceous rocks described by Griesbach and Baily, and which agree most closely with those of South India, we may here conveniently neglect; but the Uitenhage group deserves our attention all the more.

The geological age of this group has been determined with considerable certainty by Neumayr's latest work on this subject,[2] and there can hardly be any doubt that the whole group must be regarded as Neocomian.

The most important fossils with reference to this conclusion, are :—

Olcostephanus atherstoni, Sharpe.
,, baini, Sharpe.
Crioceras spinosissimum, Hausm.
Hamites africanus, Tate.
Trigonia herzogi, Hausm.
,, ventricosa, Krauss.
,, conocardiiformis, Krauss.
Ptychomya implicata, Tate.

The occurrence of *Trigonia ventricosa* in the Indian Tithonian beds of Cutch can, in view of the occurrence of the Cephalopoda just named, hardly effect much change in the above conclusion, though it may indicate the necessity of being careful.

But besides the marine fossils, plant-remains occur also in these beds, and Tate has described the following species :—

Otozamites recta, Tate.
Podozamites morrisi, Tate.
Palæozamia rubidgei, Tate.
Peterophyllum africanum, Tate.
Pecopteris atherstonii, Tate.
,, rubidgei, Tate.
,, africana, Tate.
Asplenites lobata, Oldh.
Sphenopteris antipodum, Tate.
Cyclopteris jenkinsiana, Tate.
? *Arthrotaxites indicus, Oldh.*

[1] Bronn's Jahrb., 1884, I., p. 279.
[2] E. Holub and M. Neumayr., Über einige Fossilien aus der Uitenhage—Formation in Süd-Africa. Denkschr. Kais. Akad. d. Wiss. Wien, Vol. XLIV.

Of these species two are identical with Rájmahál species from India. The others are allied partly to Rájmahál species and partly to Scarborough species. As a whole, the flora is considered as Jurassic.

The mere occurrence of *Trigonia ventricosa* in South Africa and India leads us to regard these Uitenhage beds as equivalent to the uppermost divisions of the Cutch Jurassics, the Umia beds, or the Cutch plant beds. The geological conditions are also agreeable to this. In Cutch the chief mass of the plant-beds follows the Tithonian beds, while in South Africa the plant-beds alternate with Neocomian deposits.

This is all that is known about South Africa. On the whole, there appears to be a pretty close agreement with India, but in the former region the conditions have been too little studied to admit of perfectly certain conclusions. It is highly desirable that a survey of South Africa on the Indian pattern should be established.

One uncertainty I must point out specially. According to the earlier writers it appears that the Ecca beds lie unconformably on the older formations, and that from this point a conformable succession of deposits occurs, but lately it has been asserted that they lie conformably on the older rocks, and that the unconformity appears first between the Eccas and Koonaps. As, however, the Carboniferous sandstones appear to occur only here and there, it is probable that in most places an unconformability exists also between the Eccas and the older formations.

III.—EASTERN AUSTRALIA.

Although the existence in Australia of coal seams with many fossils has long been known, the great geological features of the continent have been but little explored, and many questions which one would much like to have answered cannot be solved on the strength of the existing literature. This imperfect knowledge is due partly to the great difficulty of penetrating into the interior, but chiefly to the peculiar stratigraphical conditions of the Australian formations.

The greatest merit for the geological exploration of Australia was due to the late Reverend W. B. Clarke, and it is specially to the sub-divisions established by him for New South Wales, in the first place, that the formations of other districts must be referred.[1]

The Carboniferous formations of Australia must be of very great vertical thickness, but it is hard to make this out from what has been written about them. The succession is not everywhere the same, nor everywhere complete. Generally the carboniferous beds rest unconformably on older rocks (granite, porphyry, &c.), and the newer members often overlap the older. Silurian and Devonian formations are known (the latter limestones with many marine animal remains), but their relations to the carboniferous beds are very obscure. In the interior, and possibly representative of the more easterly marine formations, is a great deposit of yellow sandstones, which up to the present have only yielded *Lepidodendron* and a species

[1] Quite lately an entirely different scheme of formations in New South Wales has been propounded by Mr. T. W. E. David, in a paper read before the Geological Society of London, but his views were objected to in the discussion which followed the reading of the paper. But the carboniferous glacial formations are most minutely described in Mr. David's paper, and their geological horizon confirmed. Quart. Jour. Geol. Soc. Lon. Vol. XLIII, 1887, p. 190.

of *Cyclostigma*. These beds are generally regarded as Devonian. On these, Carboniferous beds are said to rest, here and there, in regular position, but as to this also there is no certainty.

The Carboniferous beds are arranged by Clarke as follows in downward succession:—

Wianamatta beds.
Hawksbury beds.
Newcastle beds.

Murce beds divided into	Upper marine beds.
	Older coal seams.
	Lower marine beds.

I shall try to describe each of these divisions rather fully.

Murce beds.—This is, for our present purpose, the more important division; because on the one hand, beds that have been formed under glacial co-operation occur here largely developed, while on the other hand, some of the deposits contain marine fossils which enable one to determine the age of the beds. There is certainly much here that has not yet been sufficiently determined, but some conclusions may be safely drawn from the facts now known.

As stated above, Clarke divides this series into "Upper marine beds," "Older coal seams," and "Lower marine beds." The whole succession of beds is probably best exposed and most accessible at Stony Creek and near Greta, where the Great Northern Railway cuts through these beds and exposes them in several cuttings, and where several bore holes and pits have penetrated the series.

According to R. D. Oldham, the series exposed both at Stony Creek and Greta is one and the same; the wings of a great anticlinal having been pierced. Clarke gives full sections of the coal pits at both places, and from these it is clear that the main mass of the beds there exposed consists of coarse conglomerate and boulder deposits, which include subordinate sandstones and shales, and near the base several coal seams. Below these seams there occur, according to Oldham, other marine conglomerates. Nearly all the beds exposed in these sections are fossiliferous; and marine animal remains as well as plants are contained here and there in the same bed.

The animal remains are all of Carboniferous type, and were fully described by L. G. de Koninck in his "Recherches sur les fossiles paléozoiques de la nouvelle Galle du Sud." In this work 74 species out of 176 have been identified with Euro pean carboniferous limestone forms. The most important are:—

* *Productus cora, Orb.*
* ,, *semireticulatus, Mart.*
* ,, *flemingi, Sow.*
,, *undatus, Defr.*
* ,, *punctatus, Mart.*
,, *fimbriatus, Sow.*
* ,, *labriculus, Mart.*
Strophomena analoga, Phill.
* *Orthothetes crenistria, Phill.*
* *Orthis resupinata, Mart.*
,, *michelini, Sow.*
* *Rhynch. pleurodon, Phill.*

* *Athyris planosulcata*, *Phill.*
* *Spirifer lineatus*, *Mart.*
* „ *glaber*, *Mart.*
* „ *pinguis*, *Sow.*
„ *convolutus*, *Phill.*
„ *triangularis*, *Mart.*
„ *bisulcatus*, *Sow.*
* *Spiriferina cristata*, *Schl.*
„ *insculpta*, *Phill.*
? *Cyrtina septosa*, *Phill.*
* *Terebratula sacculus*, *Mart.*

With regard to this list it should be specially remarked that the species against which an asterisk has been placed are distributed through the whole Carboniferous formation, and cannot therefore be used for determining the horizon more closely. Of the remaining species, M. de. Koninck will probably not be able, even now after an interval of ten years, to identify several with their representative European forms, since he has in his splendid work on the Belgian Carboniferous Limestone, admitted so much more accurate and limited an idea of species. It must be noted, however, that even with the wide meaning M. de Koninck then gave to the idea of species, no form could be identified with *Productus giganteus*, so that this whole group of forms is certainly not represented. It is important to lay stress on this, as *Productus giganteus* in particular is one of the most characteristic species of the lower and middle carboniferous series, while it is distinctly wanting in the upper coal-measures. But *per contra*, there appear in Australia numerous forms which are nearly related to forms in the Permian formations of the Salt-Range (India), *e.g.*, species of the genera *Warthia*, *Atomodesma* (*Aphanaia*) and *Martiniopsis*. All these particulars cause the general character of this marine fauna to appear as pointing with great probability to an age corresponding with that of the upper coal-measures of Europe and America.

We shall see in the course of this sketch that in Australia itself other grounds are to be found for this age determination.

According to Dr. Feistmantel's list,[1] the following remains were discovered in these beds:—

Phyllotheca, *sp.*
Glossopteris browniana, *Bgt.*
„ „ *var. præcussor*, *Fstm.*
„ *primæva*, *Fstm.*
„ *clarkei*, *Fstm.*
„ *elegans*, *Fstm.*
Næggerathiopsis prisca, *Fstm.*
Aunularia australis, *Fstm.*

Although they mostly show mesozoic characters, these plants are unquestionably found occurring together with the animal remains above enumerated.

Very important in every respect is the information furnished by R. D. Oldham, that the greatest part of the beds containing the above-named plants and animal

[1] Notes on the fossil Flora of Eastern Australia and Tasmania. Trans. Roy. Soc., New-South Wales, 1860.

remains have been formed by the action of ice. Mr. Oldham visited Greta and Stony Creek personally, and described [1] the beds thus :—

"Blocks of slate, quartzite and crystalline rocks, for the most part sub-angular, are found scattered through a matrix of fine sand or shale, and these latter beds contain delicate *Fenestellæ* and bivalve shells with the valves still united, showing that they had lived, died and been tranquilly preserved where they are now found, and proving, as conclusively as the matrix in which they are preserved, that they could never have been exposed to any current of sufficient force and rapidity to transport the blocks of stone now found lying side by side with them. These included fragments of rock are of all sizes, from a few inches to several feet in diameter, the largest I saw being about 4 feet across in every direction as exposed in the cutting, and of unknown size in the third dimension; but I was informed by Mr. Wilkinson that in these same beds he has seen boulders of slate, &c., whose dimensions may be measured in yards.

"It is impossible to account for these features except by the action of ice floating in large masses, and I had the good fortune to discover, in the Railway cutting near Branxton, a fragment beautifully smoothed and striated in the manner characteristic of glacier action, besides at least two others which showed the same feature, though obscurely. This seems to show that the ice was of the nature of icebergs broken off from a glacier which descended to the sea-level."

Such are the conditions which are found in the sections along the railway west of Newcastle, and chiefly near Greta and in the Stony Creek; but this does not exhaust all that has to be said about the Muree beds.

In other parts of the country as near Stroud, Arowa, Port Stephens and Smith's Creek, there is yet another flora which does not occur at Greta, &c., but must certainly be older than that above described. This older flora consists, according to Feistmantel, of the following species :—

Calamites radiatus, Bgt.
Sphenophyllum, sp.
Rhacopteris inæquilatera, Göpp.
" *intermedia, Fstm.*
" *cf. ræmeri, Fstm.*
" *septentrionalis, Fstm.*
Archæopteris wilkinsoni, Fstm.
Cyclostigma australe, Fstm.
Lepidodendron veltheimianum, Stbg.
" *volkmannianum, Stbg.*

These beds appear, according to Clarke's paper on the sedimentary formations of New South Wales (p. 29), to pass down into the *Lepidodendron* sandstone, but the statement is not quite sufficiently clear. According to G. Mackenzie's section of Stroud, published by Feistmantel, marine beds occur again between the plant beds and the *Lepidodendron* sandstones, and contain *Conularia, Fenestella, Productus,* and *Crinoidea,* but this marine fauna has not yet been closely studied.

Feistmantel regards the flora of these beds as certainly indicative that they are of the carboniferous limestone age.

This fact is one more reason for assigning the marine beds of Stony Creek to the age of the upper coal-measures.

[1] Rec. Geol. Surv. Ind. Vol. XIX., p. 44.

The Newcastle beds.—These consist mainly of sandstones with subordinate shales and coal seams. Their sectional thickness is unknown to me, but Clarke in a section of Burragorang gives a thickness of 716 feet. The seams yield a fairly good coal and are worked in numerous pits.

Of organic remains plants seem very common, but marine animals are entirely wanting. Up to the present the following have been described:—

Phyllotheca australis, McCoy.
Vertebraria australis, McCoy.
Sphenopteris lobifolia, Morr.
„ *alata, Bgt.*
„ „ *var. exilis, Morr.*
„ *hastata, McCoy.*
„ *germana, McCoy.*
„ *plumosa, McCoy.*
„ *flexuosa, McCoy.*
Glossopteris browniana, Bgt.
„ *linearis, McCoy.*
„ *ampla, Dana.*
„ *reticula, Dana.*
„ *cordata, Dana.*
„ *wilkinsoni, Fstm.*
„ *parallela, Fstm.*
Gangamopteris angustifolia, McCoy.
„ *clarkiana, Fstm.*
Caulopteris adamsi, Fstm.
Zeugophyllites elongatus, Morr.
Næggerathiopsis spathulata, Dana.
„ *media, Dana.*
Brachyphyllum australe, Fstm.

Of animal remains only one fish, *Urosthenes australis, Dana,* was found.

The beds are most closely connected with the underlying ones, and were only distinguished from the older division because of the absence of marine fossils and because of certain differences in the flora. They probably stand in a similar relation to the Muree beds, as in India the Kárharbári beds do to the Tálchir beds.

These beds are of special interest, as it was they which, together with the underlying Muree beds (whose separation was not at first attempted, but was only introduced by Feistmantel), led to a comparison of the Indian coal-measures with the Australian, and thus caused the former to be regarded as palæozoic. Although Feistmantel has lately attempted to show that the floras of the Damuda beds and of the Newcastle beds do not agree so closely as has been hitherto assumed, yet a large number of the species is identical. Feistmantel places the Damuda beds parallel only with the next higher sub-division, the Hawksbury beds.

The Hawksbury beds.—These are thick coarse-grained sandstones which show singular weathering forms, especially in the upper beds, and often form rock masses which are not unlike ruined castles. At the base, immediately above the Newcastle beds, come dark violet-red marls rarely interrupted by sandstones, while higher up sandstones predominate. They show yellowish or reddish to reddish-brown colours and pass frequently into conglomerates. Beds of brown ironstone in part impregnated with carbon are not rare, some attain great thickness and are then mined.

The total thickness is given by Clarke at 800 to 1,000 feet.

Fossils are not common in this sub-division, only a couple of fishes and a few plants having as yet been found. They represent the following species:—

Cleithrolepis granulatus, Eg.
Myriolepis clarkei, Eg.
Thinnfeldia odontopteroides, Fstm.
Sphenopteris, sp.
Odontopteris, sp.

It is noteworthy that in these beds again traces of ice-action are recorded. The shale beds often show a very peculiar structure. Great angular blocks of shale are often met lying together in great confusion, the spaces between them being filled with sand or small gravel. Wilkinson,[1] who first drew attention to this believes that great moving masses of ice were the cause of these appearances, that in other words they are appearances caused by the stranding of ice floes.

That ice action participated in the formation of this deposit was also confirmed by Haast.[2]

As mentioned above, the Hawksbury beds were correlated by Feistmantel with the Indian Tálchirs, and perhaps partly with the Damudas. This correlation is however not based on palæontological data, but on the fact that traces of ice-action are found in both formations. This correlation has, however, been lately much called in question by R. D. Oldham,[3] and it must be conceded that such correlation is not a very natural one. But it appears equally unnatural to correlate the Newcastle beds with the Damudas, as is done by Oldham. Much the most probable correlation is to regard the Tálchirs as the equivalent of the Muree beds, and the Kárharbáris as equivalent of the Newcastle beds. *Gangamopteris* and *Glossopteris* occur frequently in both formations, and *Gangamopteris* is common to both. The Damudas would then appear to have to be considered as of Hawksbury age, but the possibility must not be lost sight of that the Damudas may yet in part reach down to the Newcastle beds.

Wianamatta beds.—According to Clarke, these beds appear to follow the Hawksbury's with imperfect conformity; and here appears for the first time a break in sequence of the Australian coal-measures. The Hawksburys appear to have been considerably denuded before the Wianamattas were deposited. These latter consist mainly of soft shales and fine-grained sandstones which give rise to hills of rounded outline. I can nowhere find any statement of their thickness.

In the shales as well as in nodules of spherosiderite, fish and plant-remains are found, and up to the present the following species have been identified:—

Palæoniscus antipodeus, Eg.
Cleithrolepis granulatus, Eg.
Thinnfeldia odontopteroides, Fstm.
Odontopteris microphylla, McCoy.
Pecopteris tenuifolia, McCoy.
Macrotæniopteris wianamatta, Fstm.

This flora is regarded by Feistmantel as Triassic, and treated as equivalent to the Indian Damudas.

[1] Trans. Roy. Soc. New South Wales, 1879 and 1884, XIII, p. 105.
[2] Feistmantel, Rec. Geol. Surv. Ind. XIII, pp. 251-2.
[3] Rec. Geol. Surv. Ind. XIX, pp. 42-45.

The occurrence of *Thinnfeldia odontopteroides*, however, appears to me to point rather to a relationship with the Panchets. Of the fishes, *Palæoniscus* is generally regarded as Permian, while *Cleithrolepis* reminds one more of Mesozoic forms.

On the whole, the series of formations in New South Wales terminates with the Wianamatta beds: it is only here and there that yet younger beds have been found. Such beds have been described by Wilkinson as occurring in the Clarence River, and Feistmantel refers to two species of plants derived from them:—

Tæniopteris daintreei, McCoy.
Alethopteris australis, McCoy.

Both these species are important for the correct classification of particular formations which have been found elsewhere in Australia.

So far this sketch has had reference only to the succession of deposits in New South Wales, but we must turn our eyes towards the other provinces of Eastern Australia.

In Queensland, coal-measures are known belonging to two periods. The older of these, which lies more to the north, contains marine fossils of Carboniferous type and remains of *Glossopteris*, *Schizopteris* and *Pecopteris*. In these formations also traces of ice-action have been pointed out.[1]

The more southerly coal-measures are younger in age, and their flora shows the following species:—

Sphenopteris elongata, Carr.
Thinnfeldia odontopteroides, (Morr.) Fstm.
Cyclopteris cuneata, Carr.
Tæniopteris daintreei, McCoy.
Sagenopteris rhoifolia, Presl.
Otozamites cf. mandelslohi, Knor.
Cardiocarpum australe, Carr.

Feistmantel correlates the beds containing this flora with the youngest beds in New South Wales as seen in the Clarence River.

In Victoria the series is rather more complete. At the base are sandstones, which are specially well exposed at Iguana Creek, and which should probably be regarded as Devonian. They have yielded the following plant species:—

Sphenopteris iguanensis, McCoy.
Ancimites iguanensis, McCoy.
Archæopteris howitti, McCoy.
Cordaites australis, McCoy.

Over these follow sandstones known as the Avon River sandstones, which have yielded *Lepidodendron australe*. Feistmantel considers these formations to be Carboniferous.

The next higher sub-division is of great importance. It bears the name of the Bacchus-Marsh sandstone, and includes great boulder deposits of unquestionably glacial origin. The plant-remains furnished by the sub-division are—

Gangamopteris obliqua, McCoy.
" *angustifolia, McCoy.*
" *spatulata, McCoy.*

Feistmantel has connected these beds with the Hawksbury beds of New South

[1] R. L. Jack, Report on the Bowen-River Coalfield, Brisbane, 1879.

Wales; but it appears much more natural to correlate them with the Muree and New castle beds, and all of them with the Tálchir-Kárharbáris of India.

The uppermost division recognised in Victoria is that of the Bellarine beds. They are very widespread and are of great thickness. Coal seams occur, but are of small thickness and extent. Plant-remains appear to be numerous, and up to the present the following species have been described :—

Phyllotheca australis, Bgt.
Alethopteris australis, Morr.
Tæniopteris daintreei, McCoy.
Podozamites barklyi, McCoy.
Zamites ellipticus, McCoy.
,, *longifolius, McCoy.*

This flora points with great probability to a Mesozoic age of the beds containing it, and Feistmantel correlates also the Bellarine beds with those on the Clarence River in New South Wales, and the upper coal-measures in Queensland. In India the Rájmahál and Jabalpur beds should probably be considered equivalents of the formations first named.

The above are rough outlines of the conditions met with in South Africa, India, and Australia, and it will be well to bring together in tabular form the results obtained up to the present, in order to obtain a general view before we proceed to make further deductions :—

	South Africa.	India.	Eastern Australia.
Neocomian	Uitenhage ?	Cutch . { Plant beds.	? Marine beds in Queensland.
Tithonian.		Cutch . { Marine beds, Tithonian.	
? Rhætic and Jurassic.	Stormberg beds.	Jabalpur beds Kota Maleri beds Rájmahál beds	Bellarine beds. Clarence River beds. Southern coalfields, Queensland.
? Lowest Trias.	Beaufort beds	Panchet beds	Wianamatta beds.
			Unconformity.
Permian.	Koonap beds	Damuda beds	Hawksbury beds (glacial).
Upper Carboniferous.	*Unconformity*	Kárharbári beds	Newcastle beds.
Upper Carboniferous.	Ecca beds (glacial)	Tálchir beds (glacial)	Stony Creek beds. Bacchus Marsh beds (glacial).
Lower Carboniferous.	Lepidodendron beds	Resting unconformably on crystalline rocks.	Stroud and Port Stephen's beds, &c.
			Lepidodendron beds.
Devonian.	Marine Devonian	......	Marine Devonian.

From what has been said above it is evident that in South Africa, equally with India and Eastern Australia, great rock systems occur, which are rather nearly related to each other, and certainly agree with each other far more closely than with any series yet known in Europe or America. The greater part of these formations are evidently of fresh-water origin; and huge lakes and vast river systems must have occupied the regions where to-day we find the formations in question.

This observation led long since to the assumption of a great continent which in early geological periods extended over a great part of the southern hemisphere, and which in area may not have been greatly less than the present Asia-European continent.[1]

The story of this continent seems to have been a highly singular one. Instead of the great chains of foldings which compose the mountain elevations in the northern hemisphere, and form thus to some extent the skeleton of the continents; we here find table-shaped mountains built up of horizontal rock masses. These, it is true, rest on folded rocks, but the rocks effected by the folding action are principally archaic. Already in the Devonian period we see the intensity of the folding forces greatly decreased, great regions like South Africa and India show the Devonian formations mostly in horizontal positions, and whatever followed was only tilted out of its horizontal position here and there quite locally.

While the fold-making action was decreasing more and more on this part of the earth's surface, immense fallings-in appear simultaneously to have led more and more to the breaking up of the once existing vast continent. We know from the distribution of the marine deposits, that in the Jurassic period the old continents had already been separated into three independent parts; and that Africa, India, and Australia were already divided by arms of the sea: in the Triassic period on the contrary, Africa was probably still connected with India, but Australia had already then become independent.

Thus instead of increasing, the old continents shrank more and more; and probably somewhat at the same rate at which Europe and Asia emerged from the sea, the latter overflowed immense areas that were formerly *terra firma.*

At the present day only small fragments remain of the once existing southern continent, but these by the thickness of the horizontally-bedded fresh-water-formations and the mightiness of the physical processes which they reveal, allow us to draw conclusions as to the vast extent of the land to which they once belonged.

The rock systems above treated of were none of them deposited till after the cessation of the folding action. We find all the beds nearly horizontal, forming either plateau regions, or occupying shallow basins, and important stratigraphical disturbances are either local or only to be enumerated as exceptional cases of rare occurrence. The period of the fallings-in had commenced before the formation of the above-described rock systems had been finally completed. Vast areas, which had formerly been *terra firma*, were more and more submerged; and the witnesses of these events are the scanty marine deposits of jurassic and cretaceous age which we still meet with along the margins of the few remaining fragments of the ancient continent in Africa, India, and Australia.

[1] H. F. Blanford, Quart. Jour. Geol. Soc. Lond. XXXI, 1875, p. 519. Waagen Denkschr. Kais. Akad. d. W. Wien, 1878. Waagen, Rec. Geol. Surv. Ind. 1878.

It was on this continent that in times long gone by events transpired which remind one strongly of the events which happened during the quarternary glacial period in the northern hemisphere; and there was probably a time when this southern continent was mainly covered with vast masses of ice.

But when was that time? This is the great question that we have now to approach.

It has already been pointed out repeatedly that the palæontological finds in the above-described rock systems give remarkably contradictory results. If we turn merely to the Uitenhage and Cutch beds, we find in them a marine fauna pointing to a Neocomian and Tithonian age for those formations; while the plant-remains met with in the same beds are universally judged as pointing to a lower Oolitic age, and specially to the horizon of the Scarborough beds.

These contradictions between the animal and vegetable remains recur more or less in all the different sub-divisions of the systems, and become very markedly conspicuous in the Autralian Muree beds, where again marine deposits occur alternating with plant beds.

The fossil plants occurring in these beds were, and are still to-day, pronounced by McCoy, to be positively mesozoic; because in Europe the genus *Glossopteris* has only been found in the Russian Jura and in Tertiary formations, and could therefore hardly be of greater than mesozoic age in Australia. When at a later date, Feistmantel condescended to admit the Australian formations into the palæozoic epoch, it was done far less because the flora required it, than because of the marine animal remains occurring in these beds, which have a distinctly palæozoic character. But as the succession of beds, whether above or below the disputed formations, yielded no perfectly certain data for determining the age; the followers of the mesozoic age theory were at liberty to-say "the plant-remains point distinctly to a mesozoic age of the entire system, and thus it is probable that in Australia the palæozoic animal forms survived longer than in Europe, and reached up into mesozoic times." In support of this the fact could be adduced that in the present fauna and flora of Australia old types reaching up from earlier times are for the most part common, and that therefore in earlier times other old types might there be found reaching up higher than elsewhere. On the other hand, however, the species in M. de Koninck's work were so widely framed that the designation of species there used could really only be valid as group names. I myself was for some time not quite disinclined to join in these views of the phytopalæontologists, for which reason I have here and there spoken of the "So called-carboniferous deposits of Australia."

The question as to the age of these beds is now, however, of quite special interest, because of the glacial formations which are met with at equivalent horizons.

As I have already memtioned above, W. T. Blanford has striven with much skill to make a Permian age probable for the Tálchir-Kárharbári-Damuda series, and for the equivalent beds in Africa and Australia; but it was impossible for him to adduce anything more than proofs of probability, and thus no further conclusion could be based on his deductions.

It was reserved for recent times to clear up the subject; and it was the discoveries, more especially of the Würtembergian, Dr. H. Warth, in the Salt-Range which let the whole question appear in a new light.

IV.—THE SALT-RANGE.

It has long been known that in the Salt-Range also, formations are not seldom met with which have doubtless been formed under the co-operation of ice.

I have myself seen and studied these formations in many places, but till now had no opportunity of expressing my opinions about them publicly. Even now I feel somewhat embarrassed about speaking on this subject, for a remarkably unlucky star rules over everything that I publish on the general relations of the Salt-Range. Every time I am rebuffed in a manner that is really not seemly. Expressions such as "ignorance," "charlatanism," or "it would be best to regard such a paper as unpublished," are among the terms of endearment I am thought worthy of. If the writers of these knew how that I take counsel with myself for years, and consider from all points any important view before I publish it, they would perhaps judge me more indulgently. Hitherto it has not been possible for them to disprove my position; consequently I feel myself justified in still holding fast to the views which have given occasion for such harsh criticism.

The succession of beds in the Salt-Range, includes as is well known, the rock systems from the Eocene to about the Devonian (not to refer to the younger tertiary sandstones of the Potwar plateau) without showing any specially important gaps. It is equally well known that in different parts of the Salt-Range the succession of beds is very variously represented. I must here also use the nomenclature introduced by Wynne, as the application of European terms would involve too concrete a correlation, and does not at the present moment seem quite desirable.

In the eastern part of the Salt-Range the succession is as follows:—

Nummulitic beds.
Olive group.[1]
Beds with salt crystal pseudomorphs.
Magnesian sandstone.
Neobolus beds.
Purple sandstone.
Salt-marl and rock-salt.

Except the neobolus beds, the olive group, and the nummulitic limestone; this whole series of beds has yielded hardly any organic remains worth naming, and it would have been hardly possible to have determined the age of any one group in this succession from such evidence as existed till quite lately.

In the western part of the Salt-Range on the contrary, matters were quite different, as some beds occur here rich in well-preserved and characteristic fossils. The succession of beds here is the following:—

Nummulitic beds.
Olive group.
Variegated sandstone (Jurassic).
Ceratite beds.
Productus limestone (Permian).
Speckled sandstone.

[1] This te.m is now discarded; the greater part, if not the whole, in certain localities, of the series being now known as the "speckled sandstones."—*Ed.*

Magnesian sandstone } hardly separable here ; they thin out westward.
Neobulus bed }
Purple sandstone, thinning out westward.
Salt-marl and rock-salt.

The sub-division is seen to be much more varied here, and the age of several of the formations can be accurately determined. For our present purpose the "speckled sandstone" is the most important, and we will consider it more closely. By the "speckled sandstone" I understand not only what Wynne called by this name in the Salt-Range proper, but also the equivalents on this horizon in the west (the boulder group) and in the east as well (the olive group in part).

For clearer comprehension of the succession, however, it must be pointed out that the nummulitic beds and the olive group (more correctly the *Cardita beaumonti* beds) rest unconformably on all the underlying groups, and thus, if followed from west to east, they lie successively on Jurassics, ceratite beds, Permians and speckled sandstones—a circumstance which in part also causes the difference in the succession of beds in the eastern and western parts of the range. Besides this I must here rely entirely on Wynne's report, as all my own observations are woven into it. The report is in fact to be regarded as a joint one, as far as the observations in the field have to be considered. It should have been a joint one in its execution, but this was prevented by my repeated serious illnesses ; and thus Wynne was compelled, to undertake the working out of it by himself. The employment of the material has in consequence certainly often led to the different results, as if I would have disposed of them could I have influenced their being worked out. I cannot, however, for that reason entirely give up my own views, and Mr. Wynne must allow me to give them expression here and there. It is very far from my intention to ignore, on that account, the great credit Mr. Wynne has deserved by the working out of the map ; or to fail to acknowledge the admirable accuracy of his map. But now, if after having worked out the fossil faunas of the Salt-Range in great measure, I find myself constrained to lay yet greater stress on various points in the apprehension of which I did not agree with Mr. Wynne ; it will be owing to the progress made through the more exact understanding, palæontologically, of the beds. Mr. Wynne cannot possibly wish to assert that it is impossible to attain to a better knowledge of the beds than that given in his report, and doubtless his own views will have become clearer within the last ten years, as is the case with every savant unless he absolutely closes his ear against all progress.

As I stated im my introduction to the Salt-Range Fossils, the palæozoic formations of the Salt-Range are divisible into two great groups, of which the one consists of the purple sandstone and the salt-marl, the other of the higher-lying beds.[1]

[1] R. D. Oldham believes (according to a friendly communication from him) that he can show an unconformability below the speckled sandstone, while the underlying beds down to the saline series form a consistent and conformable series. As far as the unconformability is concerned, I have no objection to make to it ; on the contrary, I believe I myself made observations which allow it to appear probable, at least at certain points ; but I nevertheless believe that all the beds underlying this break cannot be regarded as belonging to one group. The magnesian sandstone and neobolus beds belong together, as certainly as it is sure that their fauna is related to that of the overlying beds although they are unconformable. But the purple sandstone shows such very close relation to the saline series, that the two can hardly be separated. The base of the latter is not exposed in the Salt-Range proper. Proceeding westward, the saline

The upper group, on the contrary, includes many littoral formations and may have been deposited by a sea that advanced from the north-west. The immense sandstone accumulations to the east of the Salt-Range, which thin out to inconsiderable beds and almost die out, appear to me to be explicable as "dune" formations, and I further believe that they indicate the embouchure of a great river which flowing from the south-east, in those long-past times reached the sea in this region. There are many points on which to base such an assumption. *Imprimis*, the Neobolus beds, as the horny-shelled Brachiopods, had probably lived in the same kind of places as the existing *lingulæ* which frequently colonize the muddy or sandy bottoms in the vicinity of river mouths; and secondly, the beds with pseudomorphic salt crystals, which indicate a tract overflowed alternately by fresh and salt water, conditions which appear most frequently in lagoons surrounding estuaries.

Under these sandstone formations, the speckled sandstones are, as pointed out above, those which extend furthest to the west, and which for many other reasons are the most important and interesting. In their uppermost beds they include a marine fauna which is very nearly related to the fauna of the Productus limestone, and for which reason I designated this formation the Lower Productus limestone. The percentage of true carboniferous species in these beds is greater than in the Productus limestone proper, and I have therefore thought it necessary to join these beds to the coal-measures specially as *Fusulina longissima, Möll.*, occurs here numerously. Perhaps they should only be correlated with the very uppermost beds of this group, *e.g.*, the Nebraska beds or the Artinsk sandstones, because of the frequent occurrence of the genera *Strophalosia* and *Aulosteges.*

Somewhat lower down in these sandstones occur boulder beds, which are to the northward and westward, the only representatives of the whole group, and occur there very constantly below the fossiliferous beds and the Permian limestones.

Unfortunately I cannot, with reference to these boulder formations, enter into as full detail as might appear desirable, partly because of the excessive length this paper would then acquire, partly for the reason that in the last volume of the Salt-Range Fossils a detailed sketch of the Salt-Range will be given, which must not be anticipated here.[1]

series continues to include more and more grey dolomites and gypsums with quartz crystals, and west of the Indus seems to pass into Wynne's generally grey-coloured upper gypsum and dolomite group. The base of this group, however, consists again of red sandstones identical with the purple sandstones of the Salt-Range proper. Thus the saline series appears altogether to be only an inclusion in a vast formation of red sandstone, which must clearly be regarded as a distinct formation. I regard this formation as an equivalent of the Vindhyans of the Indian peninsula; and from its position below the Carboniferous neobolus beds, as of Devonian age. The two groups have a very different distribution, the older occurs only in the south, and disappears in part where the other trends to the north; it would appear that the beds composing this group were formed in a great basin which extended south-eastward, probably an inland basin, and that the open sea of that part would have to be sought for further to the north.

[1] A considerable amount of new information concerning this boulder bed has in the meantime been gained through the work of Dr. Warth and R. D. Oldham (See Rec. G. S. of I., XIX, pp. 1, 22, 127, 131; XX. p. 117; XXI, p. 34), while I myself can further supplement this by my own observations this year of the decided unconformity of this boulder-bed to the underlying Salt-Pseudomorph zone, in the Khewra portion of the Salt-Range, where also, the Talchir facies of the boulder bed is remarkable.—W. K.

To the west (Trans-Indus), especially near Kingriali, Wynne distinguishes a very peculiar boulder group consisting of grey clays with subordinate sandstones and gypsums, and containing in its upper part a boulder bed of considerable thickness. The boulders are well smoothed and often marked by scratches. This boulder group is followed here as elsewhere above the speckled sandstones by the Permian limestones.

To the north-east of this lies Kalabagh, which indicates the most northerly point to which the range has deviated from its general course. Here also on the left bank of the Indus begins the Salt-Range proper, with a group of hills called the Tredian hills. Here the conglomerates are specially well developed, and are described by Wynne as follows: [1]

"The carboniferous limestones below often contain much chert, both black and white; while grey conglomerates and sandstone bands occur in the dark conglomeratic purple clay above the salt-marl. * * * * Immediately over the earthy part is a large boulder-conglomerate containing blocks of granite, syemite, and other crystalline rocks 2 feet in diameter; this conglomerate, if it has not slipped upon itself, may be 155 feet in thickness." Above this occur traces of the speckled sandstone.

We herewith enter upon the domain of the true speckled sandstone. This section is, as Wynne himself describes it, conglomeratic in many places, and the conglomerates appear frequently as true boulder accumulations, particularly in the region of Makrach and Sardi. As is usually the case, these boulder beds are not too regularly stratified, and it is hard to say whether they occur at absolutely the same horizon at different places; they are, however, irrespective of small vertical differences, geologically speaking of the same age. The position is always such that one must conceive the boulder beds as underlying the *Fusulina* beds.

The speckled sandstone attains its greatest development between Varcha and Nr-singpohar, and from there thins out rapidly to the eastward, but without losing its boulder accumulations. Quite gradually, the intercalated clays assume a red colour, but the boulder beds become green; and thus two new groups are developed, namely, the "pseudomorphic salt-crystal zone and the conglomerates of the olive group." The most western point from which Wynne quotes the boulder conglomerates of the "Olive group" is Karuli. Here they lie upon the speckled sandstone, and probably on the middle division of that group. Still further to the west the olive group is, it is true, also clearly developed, but here, as for example at Nilawan, it rests on the fossiliferous beds of the Lower Productus limestone. No trace exists of any boulder formations at the base of the group, and we must descend to the speckled sandstone to find any such again.

The boulder conglomerates of the olive group have of late attracted special attention, as fossils have been found in them which agree with fossils obtained from the Australian marine Carboniferous beds. I published a note [2] on these, but by so doing again stirred up a hornet's nest, and was rebuffed by R. D. Oldham in anything but a civil style.[3]

The olive series, as described by Wynne, contains in its upper division an equi-

[1] Mem. Geol. Surv. Ind., Vol. XIV, p. 258.
[2] Rec. Geol. Surv. Ind., XIX 1886, p. 2.
[3] Rec. Geol. Surv. Ind., XIX, part II.

valent of the *Cardita beaumonti* beds of Sind; in the lower division the much contested boulder beds. In these latter, nodules[1] of clayey sandstones were discovered by Warth, which contain inumerable specimens of *Conularia.*

These nodules form a thin bed in the uppermost part of the boulder bed, and have up to the present yielded the following fauna:—

Bucania cf. kattaensis, Waagen.
Conularia lævigata, Morr.
" tenuistriata, McCoy.
" cf. irregularis, Kon.
Nucula sp. ind.
Atomodesma (?) warthi, Waagen.
Aviculopecten cf. limæformis, Morr.
Discina, sp.
Serpulites warthi, Waagen.
" tuba, Waagen.

To these I can now add *Spirifer vespertilio, Sow.*, from specimens recently sent over by Dr. Warth. This entire fauna is distinctly palæozoic, and there is not a single species present pointing to other formations. Four of the species are identical with Australian carboniferous species, namely:—

Conularia lævigata, Morr.
" tenuistriata, McCoy.
Aviculopecten cf. limæformis, Morr.
Spirifer vespertilio, Sow.

A *Bucania cf. kattaensis, Waagen,* is comparable with another out of the uppermost divison of the speckled sandstone, the so-called lower productus limestone.

According to Wynne and Oldham, these nodules occur as washed-up specimens. And as chief proof of this the rare occurrence of rolled specimens of *conularia* is adduced, and also the fact that the nodules do not contain the organic remains in their centre like proper concretions, but that the fossils appear cut off by the surface of the nodules in the most various ways; for which reason they must be regarded as rolled rock fragments.

As regards this last proof, it is of no value. I need only refer to the quartzite nodules in our Silurian stage Dd 1, which show precisely the same conditions, but of which it is known that they contain precisely the same fossils as the shales in which they lie, and where, therefore, there is no room for any doubt that both are contemporaneous, and that the nodules cannot possibly have been transported. Here in Bohemia also, minute nodules which bear on their outside fragments of rolled-up *trilobites* or similar organic remains, are found here and there with the other quartzite nodules. They would certainly be regarded as rolled pebbles if they did occur together with other fossils, and contain the same species. This is manifestly an example of imperfect formation of nodules.

The apparently rolled specimens of *conularia* may probably be explained in this way; but on this point I cannot express a positive opinion, as I have not seen the specimens examined by Wynne.

H. Warth sent me lately such an apparently rolled specimen of a *conularia,* which

[1] And pebbles, as described by Warth and Oldham.—W. K.

at the first glance looks certainly very much as if it had been rolled. On closer examination, however, various doubts arise.

In the first place, the size of the specimen, which measures 60 millimetres in length, and 20 millimetres in width at the upper end, but is only 11 millimetres thick. When such a thin elongated body of soft sandstone is exposed to such rough treatment as it must necessarily have undergone when moved along with the conglomerate masses, it is certainly very astonishing that it was not broken into smaller fragments. Then, two of its sides and one edge had been preserved almost intact, although covered with the most delicate sculpturing. Now, an angle is certainly one of the most prominent parts of the shell, and must, when rolling takes place, be first worn off. Of the well-preserved sides, the broader one certainly is concave, and might in consequence have escaped the effects of being rolled, but the other is, in consequence of a peculiar deformity of the specimen, much bellied out. Yet here also the most delicate sculpturing is preserved. I must here remark that the specimen sent to me by Warth is quite enclosed by the matrix, a coarse conglomerate sandstone, and that thus the objection that the piece was perhaps derived from a larger rolled fragment whereby the well-preserved sides being enclosed in the fragment were protected from the wear and tear of rolling, falls to the ground entirely.

Thus in this case also it appears more probable on closer study, that the peculiar preservation of the specimen was due rather to incomplete nodule-formation than to rolling. If the specimen had really been transported and embedded for a second time, it cannot have been brought more than a couple of thousand paces, otherwise the preservation of the sculpturing in particular parts would be utterly inexplicable.

Distinct proof of the "washed up" character of the nodules appears to me not to h ve been brought forward in Wynne's and Oldham's statements. That would only have been accomplished if they had found fossils of more recent age mixed with older ones. Violently though Oldham defends his views, he cannot produce such evidence.

For all that, I certainly do not assert that the possiblity of the washed up natuie of the nodules is absolutely excluded, as I have not been able to revisit the localities since the discovery of the nodules; but a probability of that origin does not appear.

Even if they were washed up, they can only have been derived from a bed differing but little in age from their present site: nor can their original home be far removed from the place where they are now found. A proof of this is the completeness (? restrictedness[1]) of the fauna which they include, and which points to a common site and common origin. But such completeness can only be preserved when the bed which encloses the specimens has been but lately formed (and thus more recent formations could not have been affected by denudation), and when the specimens were only transported a short distance.

If we look around among the formations of the Salt-Range to see from which the nodules might possibly have been derived, if derived they were; we see that it is the magnesian sandstone alone with the Neobolus beds which could have yielded such

[1] Translator, R. B. F.

specimens. But if this be the case, and the nodules emanate from the magnesian sandstone, then this formation must advance upward suddenly into age of the Coal-measures, though they have hitherto been regarded by me as lower Carboniferous.

Shall this be the revision that my views on the Salt-Range are to undergo, as was hinted by Medlicott? Fresh facts were lately collected by Dr. Warth, which threw much new light on the whole question.

In the Nilawan, Warth found the *Conularia* nodules in boulder beds, which appear to follow immediately above the Neobolus beds, and which certainly lie at the base of the speckled sandstone. Here there is now no doubt possible that the *conularia* nodules are older than the *Fusulina* beds which occur in the immediate vicinity of the place of discovery.

There is yet something to be said about the age of the boulder bed. It was regarded by Wynne as Cretaceous, as he united it with the overlying *Cardita beaumonti* beds, which may probably be regarded as uppermost cretaceous, or as an equivalent of the Lamaric group or of the Liburnian stage.

R. D. Oldham insisted most strongly on the cretaceous age of the boulder bed, and maintains that it is unconformable to the underlying beds. Of such an unconformability neither Mr. Wynne nor I myself have seen anything. On the contrary, I have measured sections in which a perfect transition from the underlying beds of the salt crystal zone to the boulder beds could be traced, which was effected by an alternation of green and red sandstones and shales.

But in this respect also there is no reason for being compelled to unite the boulder beds with the upper instead of the lower beds. That such a boulder bed should not always lie as regularly on its soft foundation as is the rule with other formations is in the nature of things. But then such a deposit came to pass under quite unusual circumstances.

In these boulder beds of the olive series [1] their glacial origin is as distinctly expressed as it can possibly be wished.

The boulders and shingle consist most largely of red porphyry, and innumerable specimens show distinct grindings and scratchings. Very many are ground on different sides—a proof that they were at various times impacted in the ice-mass in different positions, while it was still moving. I give herewith illustrations (Plate 1.) of two such pebbles, the larger consisting of porphyry, the smaller of a blackish-grey aphanitic rock, and of which the larger is polished on the back and front sides, the smaller on three contiguous sides. The direction of the scratches is different on each polished surface, but scratches often occur on the same surface running in directions crossing each other.

If we review all that has been said up to the present with regard to the boulder beds of the olive series, we shall arrive at the following conclusion:—

(1) The boulder beds appear in the olive series just where it is in contact with [2] the speckled sandstone; while further to the west they are only found in the speckled sandstone in which they occur frequently.

[1] "Olive series" might here be better read "Eastern Salt-Range."—W. K.

[2] ? For "is in contact with," one might here read "passes longitudinally into" or "replaced by."—W. K.

(2) The speckled sandstone can, from its position below the Permian limestones and from the fossil contents of its uppermost beds, be regarded as certainly an equivalent of the uppermost section of the coal-measures.

(3) In the boulder beds of the olive series are nodules, in which, out of 11 species of fossils contained in them, 5 can be identified with species from the Australian coal-measures, and one identifiable with a species from the speckled sandstones.

(4) These *conularia* nodules which occur in the boulder beds of the olive series were lately also discovered in boulder beds in the Nilawan, which certainly lie below the *Fusulina* beds.

As all these conclusions point with great certainty in the same direction, it is difficult not to assume that the boulder beds of the olive series are to be regarded as a partial equivalent of the speckled sandstone, and are approximately of the same geological age as the boulder beds which are met with so largely developed at the base of the Permian limestone.

Hereby we have gained for the Salt-Range a great uniform glacial horizon, which is of very special importance for a right understanding of the great questions which have to be solved here.

It is true that quite lately voices have been heard giving expression to the opposite view; and R. D. Oldham asserts, in a paper in the *Geological Magazine*, that not less than four distinct horizons exist. Unfortunately no new facts have been adduced, and so Oldham's view cannot indeed bring us to give up our own well-weighed view. Such acceptations of the case always go back to Croll's theory that the glacial periods on the earth were as common and as cheap as blackberries—a theory which is in no way supported by the geological facts observed in general. The view that all the glacial formations in the Salt-Range should be reckoned to one and the same group, in no way strains the observations made by Wynne or myself, and can therefore pass as the right one till striking proofs to the contrary are brought forward. I shall have an opportunity further on of returning to the statements about the existence of numerous glacial horizons one above the other in one and the same region.

Other statements made by Oldham in the same paper deserve fuller mention, as they add fresh tracts of glacial formation to those already known in India, and at the same time give information as to whence the glacial gravels of the Salt-Range were probably derived.

In the great Indian desert which stretches from the Arvali range to the Indus, Oldham found, near to the town of Pokran, a land surface consisting of porphyry and syenite which is completely covered with scratches and striations. On this surface lies an extremely tenacious glacial mass, which Oldham claims as Till or Moraine profonde, while in the neighbourhood bedded glacial formations, manifestly of marine origin, occur widely distributed. In the Moraine profonde are only gravels of porphyry and syenite; in the marine formations on the contrary chiefly gneisses and granites which emanate from the Arvali range. Oldham believes, then, that the glacial gravels of the Salt-Range also came from the south, partly from the porphyritic continent, partly from the Arvali Mountains. Oldham assumes also for these formations the age of the Tálchirs.

In a former paper I observed already that I regarded the glacial formations of

the Salt-Range as marine throughout; but I believe not only that great glaciers descended from the Arvalis to the sea, as is assumed by Oldham, and there broke up into icebergs, but much more that the great river, the probable existence of whose mouth in the eastern Salt-Range I mentioned above, carried down to the sea vast floating masses of ice.

However all this may have been arranged, it retires completely into the background in comparison with the great general questions which have yet to be solved here.

The most important of these is the question as to the age of the glacial beds. We have established for the glacial deposits in Australia and Africa that they rest on lower carboniferous formations, and in Australia they contain a marine fauna which points to the age of upper coal-measures. This is opposed by the accompanying plant-remains which are regarded as mesozoic.

We have now, however, become acquainted with glacial deposits which underlie Permian limestones, and actually contain indications of the Australian coal-measure fauna which there lies in glacial beds. According, therefore, to all the laws of synchronism there can be no great doubt that the glacial formations of the Salt-Range are to be regarded as approximately contemporaneous with those of Australia, in which the same fauna occurs. Thus, then, the geological age of the glacial period under consideratton would seem to be altogether settled.

In Australia we have unquestionably lower Carboniferous deposits, Culm measures as their foundation: in the Salt-Range we have beds of undoubted Permian age overlying them directly. Thus nothing remains for us but to assume that the glacial events which we have been discussing took place at a time when elsewhere the upper coal-measures were being formed. The conclusion of the phytopalæontologists, which was referred to above, that in Australia the plants must be the determinants, and that the palæozoic animal types must there have lived on into the mesozoic times indicated by the plant-remains, has thus become quite untenable, and we know now for certain that in Australia, Africa and India, a flora of mesozoic type appears already at the time of the coal-measures. But this is a result of the very widest range, that includes within itself a multitude of further conclusions.

First of all let it be pointed out that the new flora appears elsewere with glacial formations, which is a clear proof that it could bear low temperature and was at the least capable of resisting night frosts. In Australia, as in Africa, this new company of plants dispossesses a series of true carboniferous plant types, as the *Calamites* and *Lepidodendra;* and the gap between the older and newer flora is so great that hardly a single genus is common to both. Under these circumstances, it is quite allowable to assume that the first distinctly palæozoic flora met its end through the advancing cold which the commencement of the glacial period diffused over the great southern continent. What else should have brought about this destruction, since at the same time on other parts of the earth's surface, where equally clear traces of the advent of severe cold are not to be traced, this same flora was at its highest development, and the formation of the coal-measures went on undisturbedly? We have therefore gained a measure for the temperature conditions to which the plant families unite their existence. The palæozic floras, consisting mostly of delicate organisms, were evidently unable to endure lower temperatures, and were bound

to perish as soon as more frequent and more severe frosts commenced. The younger flora on the contrary consisting of mesozoic types evidently contained organisms, which being stronger could resist the lower temperature, and were thus capable of accommodating themselves to more varied conditions of life.

A further inference arises necessarily out of the above, namely, that the younger flora, consisting of mesozoic plant types, was developed autochthonously in the great Africo-Indo-Australian continent; for we find in no country on earth the smallest tittle of evidence that will allow us to conclude that mesozoic plant types had developed anywhere in periods preceding the formation of the coal-measures, and had spread themselves by migration over the southern continent.

A *per contra* assumption immediately suggests itself: that the mesozoic floras of Europe which all show a great typical resemblance, are to be regarded as descendants of the palæozoic flora, which came to be developed on the southern continent during the coal-measure period.

The chief point, however, is always the proof of a glacial period which appeared on the southern continent during the coal-measure epoch, for all the other conclusions are based on this one fundamental fact. But this fact can no longer be doubted since so many observers in many quarters have, quite independently of each other, arrived at the unanimous result that the formations in question came to pass under the influence of ice. Only the settling the age of the formations was doubtful, but this can now be carried out with great certainty.

The glacial formations of this period are spread over an immense area of the earth's surface. They begin in about 40° south latitude and stretch away to about 35° north latitude, and in lougitude from about 35° east of Ferro to 170° east, an area including more than a quarter of the earth's surface, and in extent and size not much inferior to that affected by the most intense action of the quarternary glacial epoch. Bu' while during the quarternary glacial period the northern hemisphere suffered chiefly, and comparatively small extensions pushed down alongside the Andes and through New Zealand into the southern hemisphere, the chief episodes of the Carboniferous glacial period took place in the southern hemisphere, with the glacial deposits on the Afghan-Persia frontier which up to 35° north latitude are but of small extent.[1] All this is obviously correct only in its most general features. Very much is yet required to give us a clear picture of all the conditio..s, and many further studies will be necessary to complete the sketch here attempt d. We ourselves must let our eyes travel still further, and first of all submit the Europe of that time to closer consideration.

V.—EUROPE.

Glacial formations have repeatedly been though' to have been discovered in deposits which precede the quarternary period more or less. We will here disregard Croll's statements, for .e thought he could point out numerous glacial formations in every system, for .ese statements can hardly be accepted as made in earnest. Far more prudently does James Geikie express himself in his classical work, "The Great Ice Age;" for to .im the glacial origin of certain beds appears

[1] According to Griesbach's data. Rec. Geol. Surv. Ind., Vol. XIX, p.

to be made out in two cases only. The conglomerates at the base of the Carboniferous in the south of Scotland, and the Permian boulder beds described by Ramsay, appear to him to be certainly glacial.

Unfortunately I could learn nothing in detail from the existing literature about the glacial horizon in the lower Carboniferous of Scotland (as to which it is really doubtful whether it should not be classed as Upper Devonian). I succeeded, indeed with great trouble, in procuring the descriptive text to the geological map, but could find no fuller information in it. Indeed, in England itself the view that these formations are glacial seems to have been given up again more or less. Archibald Geikie in his *Text-book of Geology* lays no great stress on these statements : and lately at a meeting of the Geological Society of London, striated pebbles derived from these beds were shown in order to prove how such scratched gravels could be produced in a secondary way by the sliding of the beds.

It is quite different with regard to the glacial horizon in the Permians which is by all authorities unanimously regarded as unquestionably glacial. I shall later on have an opportunity of inquiring more closely as to this Permian glacial horizon, but for the present we will confine ourselves to the Carboniferous proper. The glacial horizon above referred to at the base of the Scotch Carboniferous appears to be at the very least doubtful.

Only a year after Ramsay had shown the glacial nature of the Permian breccias in England, Godwin Austen[1] mentioned masses of rock out of the conglomerates underlying the coal-measures in France, which masses were of far too great dimensions to have been carried to the sites they now occupy by any other agency than that of floating ice. Although the blocks are described as more or less angular, such a fact, in the absence of other parallel facts, such as polished and striated gravels, hardly suffices to stamp such formations as certainly glacial. The formations may appear to some extent suspicious, but it is hardly possible to base further conclusions on such data, especially when they have been observed only singly and not at many places.

The same holds good probably with regard to the rounded rock masses known from Silesian coal-fields and the Ostraver basin, about which so much has been said of late.[2] These rounded masses occur in the coal itself, and are often of considerable weight (one block of granulite weighed 55 kilogrammes). These blocks had evidently fallen into the coal from above while it was still in a soft peaty condition, and it would appear that the distance whence they were borne must have been a considerable one. It is therefore all the more difficult to say how the transport may have been effected. It would be most easy to assume that ice had been the agent; but it is dangerous to draw such sweeping conclusions from such isolated facts, as other possibilities cannot be absolutely excluded. Various writers have already pointed out that trees can remove rock masses, entangled in their roots, over great distances, and that perhaps some such cause might be assumed to have operated in the cases in the coal-measures. It must certainly be borne in mind that the trees of those days were only occasionally possessed of a plexus of roots in which rock-masses could fix themselves; but on the other hand, the carrying power of those spongy

[1] Quart. Jour. Geol. Soc., Vol. XII, p. 58.

[2] See Stur., Jahrbuch d, K. K Reichsanstalt, 1835, Vol. XXXV, p. 627.

woods may have been greater than that of the compact woods of the existing trees. In any case, the conditions under which those rock-masses were transported must have been very unusual ones, as indicated by the very rare occurrence of such rounded masses in the coal-measures. Anyhow, the occurrence of those rounded masses does not suffice to demand the assumption of a quasi-glacial period at the time of the formations of those coal-measures in Europe.

If the occurrence of solitary large rock-masses in a bed, or even the presence of great accumulations of boulders, were a sufficient proof of once existing ice-action, then no region could well be richer in old glacial formations than the Gailthal Alps. Gigantic boulder beds occur there at very different horizons (green Carboniferous breccias, Uggowitz breccia, Verrucano conglomerate), and if only the general fashion of the rock is regarded, these formations might decidedly be considered glacial. In no case was I able to demonstrate specially the glacial character of these deposits. In the autumn of last year (1886), I specially visited the carboniferous outcrops of this character in the Nœtschgraben, near Bleiberg, on the occasion of several excursions.

The section of the Nœtschgraben was described by Suess[1] in his accustomed masterly style. The lowest exposed rocks are the Carboniferous limestones and shales which are described by Suess as follows:—"The beds underlying the argillo-micaceous shales have a similar composition, but are coarser. They contain quartz veins of precisely similar character to those in the argillo-micaceous shales. Somewhat deeper down appears a green tufa-like rock in company with another dark-green rock, the so-called diorite of Bleiberg. These two latter appear to be connected by transitions.

"Immediately below these lies in thick beds the light-coloured quartz conglomerate of the coal-measures, just as it appears at Kerschdorf at the base of the argillo-micaceous shales. It is accompanied by beds of sandstone, and sometimes these are underlaid by soft black shales whose surfaces are covered by minute spangles of mica. The thicker lower division of these contains various marine fossils, amongst which small *Producti* and *Fenestella plebeia* are the most common; traces of fern-fronds and *Calamites* are mixed up with them. Below these follow some beds of black carboniferous limestone full of *Productus giganteus* and *Poteriocrinus* and stems of *Cyathophyllum*. These are accompanied by a very hard dark-green breccia. Once more follows black shale and again black limestone with *Productus giganteus* and *Poteriocrinus*. These are underlaid in uninterrupted southerly dip by a yet greater mass of those green diorite rocks which were mentioned at the boundary against the argillo-micaceous shale, and with these reappears the dark breccia which acquires a very remarkable appearance, especially where its blackish-green matrix encloses numerous pieces of white granular limestone. Below the American smelting furnace a new bed of black limestone cropping out from below the above contains innumerable huge shells of *Productus* with *crinoidal* stems and *Cyathophyllum*, and is traversed by red threads of gypsum."

It is the dark-green breccias which appear as true boulder beds, and to which my observations have special reference.

[1] Suess, on the equivalents of the "Rothliegende" in the Southern Alps. Sitzungsbericht Akad. d. W. Vienna, 1868, Vol. LVII, pt. I.

These boulder beds are apparently, but somewhat irregularly, intercalated between the beds with *Productus giganteus*, and which have yielded the fauna described by M. de Koninck. The fossiliferous beds become equally irregular in the neighbourhood of the boulder accumulations, are much bent and seem often to have slid together. The boulder heaps themselves frequently show no bedding of any kind, consist mainly of boulders lying together in wild confusion, and often attaining nearly to the size of a cottage, but are otherwise very varied in size, and show as matrix a fine green sandy material (perhaps Diorite tufa?) that appears mixed with more or less coarse sand and gravel. The boulders themselves consist mostly of green, more or less, aphanitic rocks; but other rocks are not rare. They are never perfectly angular, but mostly half-rounded, and perfectly rolled pieces are also not wanting. The individual accumulations of boulders appear not to extend far horizontally. Despite very close searching I could not find a trace of a polished and scratched pebble, and it thus becomes very problematic whether one is dealing at all with a glacial formation. To me the idea that these boulder heaps came to pass by the co-operation of two other factors, appears much more probable; namely, surf and torrent actions. The torrents even to-day remove the same boulders from the beds and carry them away. The beds in the Nötschgraben were doubtless formed in a shallow very near the coast, and thus both factors could exert influence on the formation of the accumulations. The colossal power surf can display I was able to study during a whole winter on the coast of the Bay of Biscay, where rock masses from 2 to 3 feet in diameter in each direction were dashed by the surf waves against the coast with such fury that the groaning of the rock-masses actually overpowered the thundering of the surf.

From this example it becomes clear how careful we should be not to pronounce any boulder bed to be glacial, unless on the one hand polished and scratched pebbles allow of a sure recognition of the glacial origin, and on the other hand, parallel facts permit of the idea of a radical change of climate.

Formations appearing on the most varied horizons in one and the same neighbourhood, which are all declared to be glacial, must from the outset arouse a certain suspicion, and the greater number of statements concerning glacial deposits at different levels in the palæozoic, mesozoic and tertiary epochs, might in the course of time come to have reference only to such totally non-glacial accumulations; or there might be errors in the determination of the ages of the beds, so that when really glacial formations occur they may be referable to but one or to very few horizons.

As I write this, an essay by Dr. Warth, which appeared in the second part of the Records of the Geological Survey of India for 1887, has come to hand, and brings the definitive proof that the four glacial horizons which R. D. Oldham maintained are all to be referred to one single level. The same thing will probably happen to the numerous glacial horizons which have been thought to be demonstrable in the Himalayas. On the one hand, they will probably prove to be mere boulder beds; on the other they will perhaps be reducible to one horizon that will approximate to the horizon of the Salt-Range.

Let us return to Europe, after this digression. We have seen that in the palæozoic formations of Europe there are no absolutely undoubted glacial formations except

in the Permian, but these stand above all doubt. The Permian glacial beds of England were described by Ramsay in a masterly way. They occur in the midland counties, and extend thence over very considerable areas and frequently attain to a thickness of several hundred feet. The blocks are either angular or half-rounded, and often from 3 to 4 feet in diameter. The surface of the greater number of them is smoothed, very many are perfectly polished and bear fine scratchings, which are either all parallel, or belong to different systems crossing each other at various angles. These boulders lie in a red marl and consist nearly all of Cambrian quartzite, of various Silurian rocks and of others of the upper Caradoc, and all must have been carried a distance of at least 20 to 40 English miles.

What place these breccias hold in the Pemian stratigraphical sequence is a little difficult to determine. Underlying them are sandstones and red marls which have yielded *Lepidodendra*, *Calamites* and (?) *Strophalosia*, and which in their turn rest unconformably on the beds of the upper Carboniferous. The breccias are certainly of marine origin, and belong either to the middle division, or the lower section of the upper division of the Permian. Similar breccias have been pointed out in Ireland and Scotland.

We must thus assume, for a great part of the British Islands at least, at the time of the Middle or Upper Permians, glacial conditions under which the breccias in question were formed. Ramsay, it is true, believes that many also of the "Rothliegende" breccias on the Continent are of glacial origin, but nothing more has been made known about this. Here, however, another fact of great interest has to be taken into consideration; the fact, namely, that in all Europe the transition from the palæozoic to the mesozoic type of the floras, and the dying out of the greater part of the palœozoic plant types, occurs in the middle of the Permian epoch, and is thus again coincident in time with the glacial phenomena described from England. We see thus that in Europe also the thorough change of the flora goes hand in hand with the change in the climatic conditions.

From North America also boulder beds of similar age are cited, but it is not decided positively whether they are really glacial or not. It appears certain however, that at the time of deposition of the Permians a great part of the northern hemisphere was visited by a great depression of temperature. What had happened to the southern hemisphere, already in the upper coal-measure period, only befel the northern hemisphere in Permian times. In each case, however, the thorough change in the temperature conditions is also mainfested in the thorough change of the flora; and by the conditions obtaining in Europe we are led to the same conclusion as we expressed above with reference to the facts observed in the southern continent, that the carboniferous plant types must have been very delicate in their nature and unable to withstand severe frosts.

The Permian cold period in Europe does not, however, seem to have been limited to the northern hemisphere. If we turn to the tabular statament on page iii we see that in the Hawksbury beds in Australia, glacial conditions occur again. These beds should very probably be considered equivalents of our Permian; and thus we should have to note in Australia also a return of cold in Permian times. But here the cold has not acted so effectually; it met with a vegetable community which could endure it, and had previously in part experienced something of the kind, and in consequence we do not see any thorough change of the flora.

In India, traces of the younger carboniferous glacial period seem to be wanting. In the Salt-Range, the older very thick glacial deposits are overlaid by beds with *Fusulina longissima, Möll.*, and some other species, and these are followed by the rich Permian fauna described by me. This fauna is by no means an autochthonous one, for it consists of a community of organisms thrown together like dice in a variety of ways.

The greater part of the fauna emanates from the east from China, which had already in the upper Coal-measure period been colonized from America, as is clearly taught by the Lo Ping fauna described by Kayser. A colonization at such an immense distance can only take place under specially favourable circumstances aud with the assistance of marine currents. It was these probably which made the climate of China so much milder that the formation of the coal-measures could continue uninterruptedly, while in the neighbouring India great ice-masses were being heaped up. These ocean currents extended in the Permian time as far as the Indian coast of the great southern continent, and by bringing warm waters with them caused there the rich development of organic life with which I became acquainted in the Productus limestone. From this source spring also the majority of the species of the Indian Permian. Another, but smaller number of them, indicates a connection with the carboniferous fauna of Australia. According to the observations of R. D. Oldham, the latter is embedded in the glacial deposits, and may well therefore be considered as a cold-water fauna. If regarded from this point of view; it is explicable why so few types of this fauna, of which indications occur in the glacial beds of the Salt-Range, have survived into the Permian deposits. A third almost invisible fraction of the fauna points to relations with the north (the lands of the Caucasus). But the richer the Permian fauna enclosed in the Productus limestone appears, the more remarkable does it seem that this fauna appears to be suddenly cut off without any transition forms, as soon as the first deposits of the *Ceratite* beds, that is to say, the lowest Trias, appear. This sudden disappearance of the palæozoic animal types in India brings us to another question that has yet to be discussed,—whether the great depression of temperature, which was followed by the above described glacial phenomena, and which showed as its immediate result the extinction of the palæozoic plant types, had also similar influence on the marine faunas, and caused the reduction of the palæozoic animal type to a small residue.

If we study the effect of the cold of the quarternary glacial period on the marine faunas, we see that an extinction of the types is not caused immediately, but that only a horizontal displacement of the faunas sets in, and they thus accommodate themselves in this way to the conditions of temperature.

So, also, in that long past time to which the above described glacial formations belong, the approaching cold will from the first have had that effect, and the several faunas will, from the first, have sought the places in which the conditions of temperature agreed with the conditions of life essential to them. But when in addition to the greatly lowered temperature another distribution of the great continental land-masses takes place, which is followed by a totally different distribution of the ocean currents, then a state of things will appear at many points of the earth's surface which offers no longer the life conditions necessary for a community of marine organisms accustomed to a high-water temperature, and they will have to perish wholesale,

so that only a small nnmber will be able to save themselves and reach a fresh period.

Such a case doubtless occurred in the Salt-Range, while, at the time of the second carboniferous cold period, warm currents flowing here from the east favoured a rich life; but this current was at the Permian period suddenly diverted and replaced by a cold current from the far north.

That this was really the case is proved by the enclosed fossils; for, with the lower beds appear suddenly Siberian cephalapoda types (*Siberites*, &c.) in great numbers. This marine current continued throughout the Triassic and Jurassic periods, and caused a deep descent to the southward of the boundaries of the Boreal marine province. For the Jurassic system, this descent was long since demonstrated by Neumayr.

Thus it appears that the possibility is not barred that the great revolution which occurred also in the fauna of the seas at the end of the palæozoic period, may be referred back, in part directly, in part indirectly, to the great depression of temperature which at the end of the palæozoic time appears to have spread itself over the whole earth, South America excepted.

As far as I know, South America is at present the only continental mass in which glacial formations have not been shown, either in the upper Carboniferous or the Permian.

The presence of a mild climate in this quarter is proven by the existence of coal-measures with genuine carboniferous plants in Brazil.

South America seems to have played a similar part during the carboniferous glacial period to Western North America in the time of the quarternary ice cap; where, as shown by Campbell, glacier traces are very sparingly present, and are restricted to the higher-lying parts of the country.

I have thus striven to demonstrate a glacial period which appeared with great intensity in the upper Carboniferous period on a continent the greatest part of which lay south of the equator; but which later in the Permian period extended itself over the greatest part of the globe. However many ice-made formations in earlier and later times have been mentioned in geological literature; at no time can such deposits be shown in such wide extension as in the Carboniferous [1] and the quarternary periods.

As far as our knowledge now extends, there appear thus to have been two great periods of cold which our earth has passed through up to the present; and of these the second seems to have been pretty nearly the counterpart of the first.

From my deductions, however, it becomes abundantly clear that in the earlier, as in the later, times, the distribution of the plant types on the surface of the earth was dependent on climatic conditions, so that plant remains can only be used as leading fossils under certain restrictions and precautions.

To enter upon the causes of the great depression of temperature in the Carboniferous period, is not in the very least my intention. Endless studies will yet have to be made ere any degree of clearness will be attained to in this respect. I would

[1] When I speak here of the carboniferous in general, I reckon the Permian as a sub-division of the Carboniferous. I do not at all believe that the Permian can maintain itself as an independent system.

only mention that the explanation indicated by R. D. Oldham in the Geological Magazine for 1886, and before that in the Journal of the Asiatic Society of Bengal, appears to me quite insufficient, as the conditions are certainly much more complicated than pre-supposed by that attempt at explanation.

The Sequence *and* correlation *of the* Pre-Tertiary Sedimentary formations *of the* Simla Region *of the* Lower Himalayas, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

Since the publication of the *Manual of the Geology of India*, there has been no general review of our knowledge of the geology of the Himalayas, yet so great has been the progress made since then, that it becomes daily more necessary that the many isolated accounts of different portions of the Himalayas should be amalgamated, so far as is possible, and a starting point for further work obtained.

As long as the survey of the Himalayas is in active progress, the individual workers are naturally loth to publish anything which, having the appearance of finality, would perhaps be superseded by the next season's work: but as my own work in the Himalayas, which has been interrupted for some time, may be suspended owing to more pressing demands made on the Geological Survey, this will give an opportunity for publishing a summary of the present state of our knowledge of the region with which I am personally acquainted.

Owing to the many interruptions of my work in the Himalayas, it is impossible for me to give a detailed account of the geology of the Simla Region, and I shall consequently confine myself to giving an account of the sequence which will be useful as indicating systems which have been identified in the region under consideration, of which equivalents may be looked for in other neighbouring regions.

"Central gneiss" series.

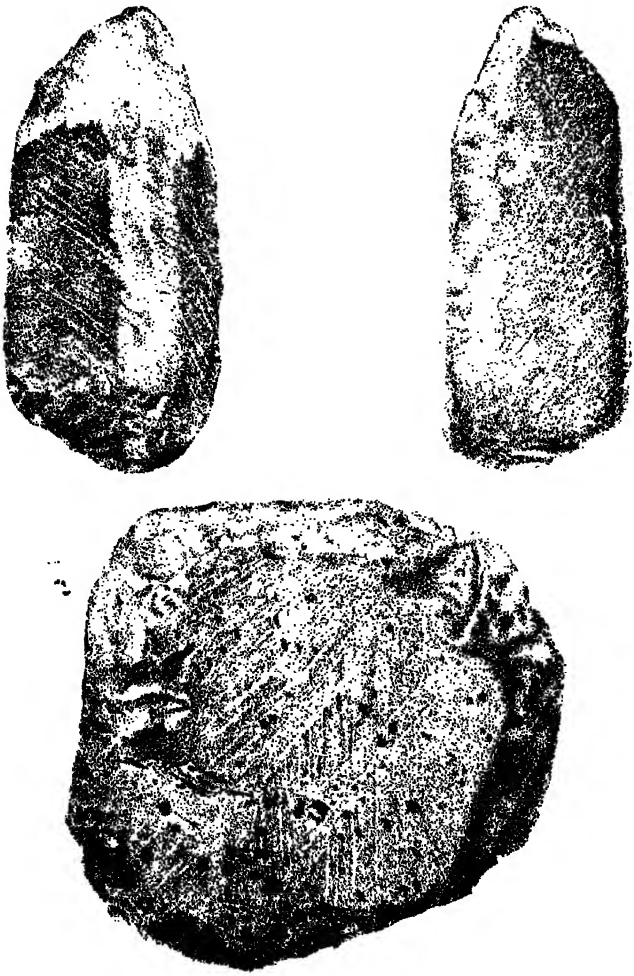
Within the limits of the Simla Region, by which is here meant that part of the Lower Himalayas which lies west of the Jumna river, the oldest series of rocks consists of bedded gneiss. The occurrence of gneiss in the Himalayas was noticed by the earliest observers, but it was first separated as a distinct system by Dr. Stoliczka, who named the gneiss, seen by him on the Babeh pass, the "Central gneiss"[1] from an idea that it formed the original axis or core on either side of which the sedimentary beds of the Himalayas were deposited.

Though the hypothesis on which this idea depended is no longer tenable, and the name, in so far as it implies a theory, inappropriate, yet as this theory has been abandoned by geologists the old name may safely be maintained as preferable to Laurentian or Archæan, both of which imply an hypothesis there is no means of verifying.

Babeh pass section.

The Babeh pass section does not strictly belong to the Lower Himalaya but is so close to the ill-defined boundary of this region that it will be considered here. On the ascent from the Sutlej river

[1] Mem. Geol. Surv. Ind., V, pt. i.



Polished and scratched pebbles from the Boulder bed, Chel Hill, Salt Range.

at Wangtu bridge an apparently continuous sequence of not less than 11,000 feet of gneiss is seen dipping at high angles to north-north-east. The rock varies in texture and composition a few thin bands of mica schist being seen, but for the most part it is a massive, often granitoid, gneiss; in some of the beds the foliation is absent or obscure and these generally contain porphyritic crystals of orthoclase, twinned on the Carlsbad type. The foliation is parallel to the bedding planes and the successive layers, varying in thickness from a few inches to a few feet, differ from each other in texture and mineral composition; showing that, whether metamorphosed from ordinary sediment or not, the rock was originally formed by some process analogous to, if not identical with, ordinary sedimentation.

Exposure at head of Pábar valley.

Beds belonging presumably to the same system, though differing somewhat in mineral character are exposed in the upper part of the Pábar valley in Bissáhir.[1] Here there is a much larger proportion of very slightly felspathic mica schists and quartzites, some of the latter being perfectly free from felspar and showing their detrital origin very distinctly; on the other hand some of the beds are almost pure orthoclase. None of the beds of gneiss are as highly metamorphosed as the generality of those on the Babeh pass section, but *augen* gneiss is abundant; in some of the beds lenticular masses of felspar over an inch thick and about three in length are scattered through the rock, the internal structure being in all cases that of a crystal twinned along a plane passing through the edge of the lens and lying parallel with the planes of foliation.

Possibly two series.

In spite of the differences between the gneiss of the Pábar valley and that of the Babeh pass I have thought it best, in the absence of any proof to the contrary, to class them together; the occurrence of *augen* gneiss in both and the fact that the most common accessory minerals are schorl and garnet in both cases, is to a certain, though slight, extent, confirmatory of this conclusion.

The central gneiss appears to occupy but a very small area within the Simla Region as here defined but it attains a great development in the Central Himalayas.

The Jaonsár system.

Next following the central gneiss comes what I shall call the Jaonsár system. This was first identified by me in the district of Jaonsár; it was named the Chakrata series,[2] and divided into an upper and a lower group. But subsequent examination of the same system where it is more satisfactorily exposed, west of the Tons, has led me to the conclusion that it should be divided into three divisions, the lowest of which was, through a mistaken correlation, erroneously classed with the uppermost.

Lower Jaonsár subdivision.

Of these three divisions the lowest consists of a great thickness of grey slates containing, towards the upper limit, a band of blue limestone about 300 feet thick. They have not been fully examined and it is not even certain whether they really belong to this system or no.

Jaonsár quartzites.

The middle division of the Jaonsár system is characterized by the prevalence of red quartzites and slates It forms the hill or which the sanitarium of Chakrata is built and there consists of purplish red slates and quartzites, the latter not infrequently mottled with white.

[1] For description see Rec. Geol. Surv. Ind., XX, 160.
[2] Rec. Geol. Surv. Ind., XVI, 93.

Unconformable to central gneiss.

The same purple quartzites are found in the Naira[1] and Bangál valleys of Eastern Sirmur, and at the head of the Pábar valley the gneiss series is unconformably overlaid by purple quartzites and slates, above which come hornblende schists, probably representing the volcanic beds of the upper group.

Upper Jaonsár.

The beds of the upper Jaonsár group are exposed in the northern part of Jaonsár Báwar, but their relations to the quartzites are better shewn in the Bangál valley in Eastern Sirmur, on the southern side of which the red quartzites and slates of the lower group are overlaid by about 200 feet of dark-grey felsitic trap covered by as much more of mixed trap and volcanic ash. This does not, however, exhibit the whole thickness of the volcanics, as their upper part is cut off by an unconformity.[2]

The volcanic beds of Northern Jaonsár differ from these in some respects; lava flows are rarer while ashes, interstratified and mixed with sub-aqueous sediment are abundant, moreover a band of limestone, some 300 feet in thickness is interstratified in the series.[3]

An old land area.

This difference is due to a difference in the mode of origin; while the volcanics of Jaonsár were certainly deposited under water, those of the Bangál valley were of sub-aerial origin. At one place a layer of pebbles, some of lava but mostly of vein quartz, was found interstratified with the volcanics.[4] The presence of lava pebbles would not prove more than the contemporary existence of a volcanic island, but the quartz pebbles point to the proximity of an area of non-volcanic rocks, whose shores must have bounded the sea area of the Jaonsár period.

Possible newer group.

On the northern side of the Bangál valley these volcanic beds are overlaid by a great thickness of sub-schistose slate, but whether it belongs properly to the Jaonsár system or a newer one is not known.[5]

Boulder-bearing beds.

Before leaving this system I must mention that a conglomeratic bed, similar to that of the Blaini group, to be described further on, has been recorded in two distinct localities, and in both cases low down in the section. The most westerly of these is on the north side of the Bangál valley. Here at the eastern boundary of the Jaonsár system, where it is faulted against the Deoban limestone, there occurs a bed of semi-schistose red quartzose slate, through which are scattered rounded boulders of hard crystalline quartzite. The position of this bed in the section is a little doubtful as the rock was not seen *in situ* but the position in which the detached fragments were found and the similarity between the matrix and some of the beds of the Lower Jaonsár group, alike indicate that it occurs low down in that system of rocks. It is important to note that the bed cannot be of volcanic origin, as is proved by the rounded, water-worn form of the boulders; and that it is not associated with any volcanic beds, being separated by between 2,000 and 3,000 feet of sedimentary beds from the upper Chakrata traps.[6]

[1] Neweli of Atlas of India.
[2] Rec. Geol. Surv. Ind., XX, 157.
[3] *Ibid.* XVI, 193 (1883).
[4] *Ibid.* XX, 157.
[5] R. D. Oldham, MSS. Report.
[6] R. D. Oldham, Rec. Geol. Surv. Ind., XX, 157 (1887), and MSS. Report.

A somewhat similar bed occurs in Northern Jaonsár, where it has been recorded as Blaini. Here the matrix is quartzite and the included fragments are angular, this combined with the presence of volcanic beds among the quartzites with which it is interbedded renders it impossible to declare that the rock is not of volcanic origin.[1] This hypothesis does not, however, seem to me to fit the case, and it is certainly equally probable that it is of the same age and origin as the Bangál rock. What may have been the origin of the latter I shall not at present discuss.

Deoban system.

Above the Jaonsár volcanics there is, in Northern Jaonsár, a great development of limestone which forms nearly all the higher parts of the group of mountains running north from Deoban. This limestone was at one time regarded as the equivalent of that seen on the Krol mountain, south of Simla; but was named Deoban limestone[2] by me in 1883 in consequence of a doubt as to the correctness of this identification. Subsequent investigation has shown that the two limestones are distinct, so the provisional name may stand. The unconformity of this system to the Jaonsár beds is very plainly seen in Northern Jaonsár and is especially well-marked in the valley of the Dháragadh where the occurrence of a band of limestone among the beds of the Jaonsár system serves as a horizon to mark the oblique truncation of the beds of the older series by the contact surface between them and the Deoban limestone.

The Deoban system as seen in Jaonsár consists of a pale grey, bedded limestone, with a varying proportion of dolomitic beds and intercalated slates. The limestone is frequently mephitic, in places contains cherty concretions, and is occasionally oolitic. A speckled limestone shewing black specks on a white ground is common and some of the beds exhibit a peculiar pseudo-organic structure which gives them the appearance of being composed of a mass of closely chambered shells; curiously enough these apparent fossils are generally imbedded in a matrix which weathers brown, while they retain their blue-grey colour.[3] The structure is possibly of organic origin, but if so, it is impossible to guess even the family of the animal that produced it, and if of purely concretionary origin it is strange that it should be found over so large an area. I have found it in Sirmur, west and south of the Giri, and a precisely similar structure was described, and illustrated, by Dr. McClelland, in the "transition" limestone of Kumaon.[4]

This system is not known with certainty to occur away from the Deoban exposure, but it is almost certain that some of the exposures of limestone south-east of the Chor should be ascribed to it, while the great limestone of the Shali peak, north-east of Simla, probably belongs to the same system.

The carbonaceous system.

Following on the Deoban there comes a system which I find some difficulty in treating satisfactorily. It probably occupies a more extensive area in the north-western termination of the Lower Himalayas than any other system of beds, but all the

[1] Rec. Geol. Surv. Ind., XVI, 193, (1883).

[2] Rec. Geol. Surv. Ind., XVI, 195.

[3] Loc. cit.

[4] Jour. As. Soc. Beng., III, 628, plate XXXV, fig. 4 (1834), see also Geol. Mag., 3rd Decade V, 255 (1888), where a similar structure from the limestone of Kulu is described, and considered as of organic origin.

sections examined as yet shew individual peculiarities, and as it is impossible to say where the system is best exposed I am driven to take a descriptive name from the slates impregnated with carbonaceous matter which characterize its upper portion, and I shall speak of it as the carbonaceous system.

Sub-divisions, Simla slates.

On the Simla section the lowest group seen consists of a great thickness of grey slates, gritty slates and quartzites, being the Infra-Blaini or Simla slates of Mr. Medlicott.[1] It is not absolutely certain whether these slates do or do not belong to the carbonaceous system, but in the neighbourhood of Simla there is no indication of an unconformity and for the present it is best to class them here.

Blaini group.

Following on the Simla slates comes a very peculiar group of beds, originally described by Mr. Medlicott, under the name of Blaini, as follows:—[2]"The principal rock of this little group is a pure limestone, very dense, ometimes compact sometimes sub-crystalline; its commonest colour is pale pink, but often blue and greenish-yellow; it occurs in thin, well-defined layers, but these are often agglomerated together into one mass, the beds shewing only as bands in this mass.* * * It has a constant companion, more peculiar than itself, and the two combined furnish an unmistakable clue. This other rock is a kind of conglomerate. It occurs, I believe, below the limestone, though in the many inverted contortions it often appears above. The base of this conglomerate is a fine, gritty slate, of a dull green or blue colour, in fact altogether like the thin-bedded rocks in the midst of which it occurs. Through this base pebbles of quartz are thinly scattered, seldom larger than a hen's egg. These pebbles are sometimes so scarce as to pass unnoticed without special search. In most places sub-angular fragments of a *slate* rock are the prevailing foreign elements in the conglomerate, which thus assumes a very brecciated aspect."

With regard to this description I must remark that there seem to me some objections to the application of the word "conglomerate" to such a rock as is described. We require some term that indicates the occurrence of pebbles scattered through, and separated from each other by, a slate matrix, a structure which involves some special mode of formation and deserves a special name. But it is necessary to choose one that does not involve a theory, and perhaps the best name that can be applied is "boulder slate," on the analogy of "boulder clay," meaning thereby a slate containing scattered fragments of foreign rock, irrespective of the actual size of these fragments. An objection to the term is, of course, that indirectly it implies a theory, the term boulder clay having become almost synonymous with glacial; this objection may be held to be of less weight, as the theory implied is the only one that satisfactorily accounts for the known facts and, in any case, there is no essential or direct connection between the term used to describe the effect and the assumed cause. I shall therefore use the term "boulder slate" as meaning a slate which encloses boulders or pebbles of some older rock, and without reference to the theoretical origin of the rock.

The Blaini group, in the form originally described, has a tolerably extensive dis-

[1] Mem. Geol. Surv. Ind., III, pt. ii, p. 33.

[2] *Op cit.* p. 30. The name was originally spelt Blini, but the more correct spelling Blaini is now generally adopted.

tribution, being found even east of Mussoorie, but as a rule the boulder slates are more extensively developed, and the limestone, even in the neighbourhood of Simla, is by no means a constant member.[1]

Carbonaceous division.

Above the Blaini group, and intimately associated with it comes the series of beds from which I have derived the name of the system. They were originally described by Mr. Medlicott as "Infra Krol" from the fact of their occurrence underneath the Krol limestone on the Krol mountain. The series is there only partly exposed and this as well the suggestion of association with the Krol limestone might be held to necessitate supersession of the name, but it has held its own for 30 years in the Survey publications and it will be best to retain it, but in a more extended sense as including the "Krol quartzite." On the Simla hill the series consists of two bands of slates and limestones more or less impregnated with carbonaceous matter, separated by about 1,000 feet of schistose quartzites and garnetiferous mica schist. These last, which have been described as "Boileauganj quartzites," most probably represent the "Krol quartzite" of Mr. Medlicott—a term I shall discard as the beds described under it appear to belong to the carbonaceous system rather than to the Krol limestone.

Volcanic beds: carbonaceous division.

In the Simla section there is no trace of volcanic activity if we except some hornblende schists occupying the summits of Prospect and Jako hills at Simla, but elsewhere, in Jubal and Bisahir,[2] volcanic beds are everywhere found in the upper part of the series. They consist of ash beds, more or less mixed with ordinary sediment of detrital origin, and lava flows; the latter have not been examined in detail but appear to be for the most part basalts, more or less altered by subsequent change, frequently amygdaloidal but as often exhibiting no indications of a scoriaceous structure. In the recorded sections they are always interstratified with sediments and the ashes are more or less impure, showing that they were formed by submarine eruptions, though the actual vents may in some or all cases have been raised above the sea-level.

It may be noted that the distinctness of these volcanics from those of the Jaonsár series is marked not only by their position in the sequence, but by the much more basic type of the rocks they are composed of.

The different sections do not agree as to the position of the volcanic beds in the series. At Simla the hornblendic rocks are in the upper carbonaceous band. In the Sutlej valley they appear to occur both above and below as well as interstratified with white quartzites like those above which they occur on the Lambatích ridge. In the Deora valley of Jubal their position is doubtful and on the eastern flank of the Chor they seem to occur near the top of the lower carbonaceous band. The general conclusion that may be arrived at is that the volcanic beds do not belong to any fixed horizon but occur with greater or less vertical extent throughout the upper part of the Infra-Krol series, and always, so far as is known, well separated from the boulder slates of the Blaini group.

[1] See Rec. Geol. Surv. Ind. X p. 204 *et. seq.*, XX, p. 158.

[2] Rec. Geol. Surv. Ind. XX, 159; the volcanic beds of the Sutlej valley described by Col McMahon also belong to this division. See Rec. Geol. Surv. Ind., XIX, 65, *et seq.*

Carbonaceous series of the Lambatách ridge.—On the Lambatách ridge, which rises north of the Tons, immediately above its junction with the Pábar, and in the north of Jaonsár-Báwar the carbonaceous series assumes a peculiar form. In the valley of the Koti gádh (Kunjado river) there is a series of coarse-grained foliated arkose rocks. Owing to the presence of large fragments of orthoclase and to the subsequent foliation of the rock it is difficult and often impossible to distinguish a hand specimen from some forms of the intrusive gneissose granite, but in the field there is little difficulty in telling the two rocks apart, not only does the arkose decompose more readily than the granite, but on looking over a weathered surface it is not difficult to find small pebbles. At a little distance, however, the huge rounded masses of the arkose are easily mistaken for an outcrop of granite.

Above this coarse-grained arkose there come foliated beds containing granules of felspar, which pass upwards into a coarse-grained felspathic quartzite or grit full of small granules of undecomposed felspar. In this rock pebbles and boulders ranging to over a foot in diameter occur, not heaped together, but scattered through the matrix of grit. The whole of the beds up to this are characterized by containing numerous granules of blue quartz. Above the conglomeratic grits come fine grained quartzites which extend across the Tons and were described by me as the Báwar quartzites;[1] they are semi-transparent where undecomposed but weather opaque white and ultimately into a very fine, sharp, white sand, owing to the decomposition of the felspathic cement; above these come volcanic beds and above them carbonaceous slates and limestones.

The conglomeratic grits above mentioned are, to say the least, not incompatible with a glacial origin; while it is difficult to understand how either gneiss or granite could have disintegrated without decomposition of its constituent minerals except under a severe climate. This combination of beds, indicating a period of exceptionally cold climate, overlaid by carbonaceous slates and limestones associated with volcanic beds seems to join these beds to the carbonaceous series, while, as an additional proof, schistose beds, characterized by the presence of granules of blue quartz are largely developed in connection with carbonaceous slates in the hills west of the Pábar river.

Mandháli beds of Jaonsár.

There remains for consideration a group or series of beds distinguished by me in 1883[2] as the Mandháli series and classed as distinct from the Blaini group. The group, as I now prefer to call it, is of the most protean character, consisting of quartzites, slates, limestones, conglomerates and boulder beds in most variable proportions and interstratified in the most extraordinary manner; it being not uncommon to find slates or even limestone interbedded with coarse grits or conglomerates This variability appears to be due to the fact that it has been deposited in close proximity to land, and always contains a large proportion of debris derived from the older rocks of the neighbourhood. Thus in Northern Jaonsár and Báwar, where it rests on the Deoban limestone fragments of that rock are extremely abundant in it and there are several beds of a conglomerate composed exclusively of rounded boulders of the Deoban limestone imbedded in a matrix of the same rock in a finely comminuted

[1] Rec. Geol. Surv. Ind., XVI, 197.
[2] Rec. Geol. Surv. Ind., XVI, 196.

form, while in Southern Jaonsár, where it rests on the quartzites of the Jäonsár series the group consists almost entirely of coarse quartzites and grits.

But the great characteristic of the Mandháli group is the presence of boulder beds of the same type as that of the Blaini group. So great indeed is the similarity that in more than one case an exposure of this group has been described as Blaini.

In Jaonsár the Mandháli group appears to be completely isolated and the rocks occurring next above it removed by denudation,[1] but on the eastern flanks of the Chor mountain at the head of the Minas gadh (Suinj R. of Atlas of India) and east of Chepál in the Jubal State beds shewing the same characteristics as the Mandháli group rest unconformably on a massive limestone, fragments of which they contain. The limestone is similar in character to the Deoban limestone of Jaonsár, with which it is, moreover, continuous at the surface; and the beds overlying it may be taken to represent the Mandháli group of Jaonsár. But these last underlie, apparently with perfect conformity black carbonaceous slates which again underlie a great thickness of quartzites and schists undistinguishable from the Boileaugunj quartzites of Simla.

Identity of Blaini and Mandháli.

This section would seem to indicate the indentity of the Blaini and Mandháli beds, a conclusion further supported by the peculiar and exceptional character of both and the occurrence of recognizable Blaini beds both east and west of Jaonsár, where, with the exception of the Mandháli beds they are unrepresented. If we take the glacial origin of the two as proved, this in itself would establish the contemporaneity of the two groups of beds which outside evidence places between the Deoban and the upper part of the carbonaceous system. The only indication of their separation lies in the fact that when examining Jaonsár in 1882-83 I separated the Mandhális from the Báwar quartzites which are here classed with the carbonaceous system. But the separation was based on the difference in disturbance of the two groups, a difference which subsequent experience has shewn me might well be due to the superior homogeneity and massiveness of the Báwars.

The Krol system.—Above the beds of the carbonaceous series there is, on the Simla section, a limestone series described by Mr. Medlicott as the Krol limestone, owing to its forming the upper part of the mountain of that name rising over the cart-road to Simla. According to him the limestone may be divided into an upper and a lower portion, the distinguishing mark being a greater preponderance of shaly beds in the lower half, though a perfect transition is stated to occur between them.

Like the Deoban the Krol is a blue limestone with frequent concretionary masses of chert. The lithological similarity is so great that they might be and have been taken for the same series, but the superposition of the one and infraposition of the other to the carbonaceous series leaves no room for doubt that they are distinct.

The Krol limestone extends south eastwards from the Krol mountain to the eastern borders of Sirmur, and in Jaonsár there occurs a newer limestone, sometimes resting directly on the Deoban sometimes with the intervention of beds of the Mandháli group, which can hardly but be the Krol.

[1] Rec. Geol. Surv. Ind., XVI, 196.

Mr. Medlicott regarded this limestone as conformable to the underlying beds, but the great variations, in the thickness of the Krol quartzite, as recorded by him, and the total absence of the great thickness of quartzites and upper group of carbonaceous beds seen on adjacent sections, point very strongly to an unconformity. If the upper limestone of Jaonsár is Krol, and it can hardly be anything else, the unconformity is unquestionable for the whole thickness of the carbonaceous series is there wanting.

As yet neither upper nor lower members of this group have been determined, though it is hardly credible that the whole sequence should consist of only a few hundred feet of limestone with shales towards the base.

A sequence of marine beds.

Such is the sequence in the Simla Himalayas as far as it has at present been determined, and throughout this vast thickness of rocks not a single fossil has been found, if we except the peculiar organic-looking structures found in the Deoban limestone, yet there can be little room for doubting that they are principally if not entirely of marine origin. The hypothesis that they may be of fresh water origin has been proposed to account for the absence of fossils, but it has never been strenuously upheld and appears to be inconsistent with the vast thickness of some of the systems or with their uniformity over an area much larger than that described as the Simla region of the Himalayas.

Only two attempts have been made to correlate the rocks of other parts of the Himalayas with those of the Simla region, one by Dr. Stoliczka in 1865, and the other by Mr. Lydekker in 1883; but since both were ignorant of any more extended sequence than that contained in Mr. Medlicott's memoir, it is not necessary to refer to them in detail.

Correlation dependent on physical characters.

As no fossils have been found in any of the rocks of the Simla region, it will be necessary to depend on the physical characters of some of the groups. Their mere lithological similarity is well known to be valueless for the identification of rock groups unless applied within a very limited area and over very short gaps. A sequence of groups each shewing certain lithological characters is more important, and where a similar sequence of similar rocks is found greater weight attaches to it than to the mere lithological similarities of single groups. But even this would fail when applied over such distances as we have to deal with.

The reason for this is easy to find, and lies in the fact that conglomerates, sandstones, shales, limestones, and any gradation between them have been forming at every period of the earth's history, since it cooled down sufficiently to allow of life, and that the formation of any particular variety of deposit at any particular place and time depends on the accidents of current, depth, and distance from shore. But the same objection does not apply to those characters which are the result of causes which act intermittently at long-separated periods and independently of the accidents which control the nature of ordinary sediments.

Prominent among such would be the traces of a glacial period which we might expect to find wherever sediment was being formed on the sea bottom.

Of less value would be the occurrence of beds of volcanic origin, for though seldom if ever confined to a single locality, volcanic energy generally begins slowly,

lasts long and is apt to recur in localities not far separated from each other at intervals which, geologically, are not of great duration.

Of similar nature may be the peculiar impregnation with carbonaceous matter seen among the shales of the carbonaceous series, for in other parts of the Himalayas similar beds are found and everywhere, so far as is known, confined to a single group in the sequence.

Carbonaceous system.

Among the many systems in the sequence of the Simla-Himalayas, the carbonaceous system exhibits all three of the special peculiarities noted above and we may consequently expect to recognize it with comparative certainty in other regions where it may exist. Among these that which most naturally comes first is the Kashmir area where the rocks more nearly approach those of the Simla region in character than do those of the Central Himalayas.

In the Cashmere region Mr. Lydekker[1] divided the sequence of pre-tertiary rocks into three systems :—

3.—The Zánskár system.
2.—The Panjál system.
1.—The Metamorphic system.

These three systems are described as not only conformable in themselves but are spoken of as conformable to each other; the metamorphic system is regarded as palæozoic (Cambrian) while the newest beds of the Panjál system are Cretaceous. Such an enormous conformable sequence of rocks, stretching from early palæozoic to latest secondary times, is not only in itself unusual but is directly contrary to what we find to be the case in other parts of the Himalayas; and it becomes necessary, in consequence, to enquire into the grounds it is based upon.

The metamorphic system is regarded as composed of gneiss of two distinct ages, one archæan, the other composed of metamorphosed beds of Panjál age. This is not in itself impossible, for, though the general tendency of modern geologists is to regard a gneiss series as necessarily older than a slate series, it is by no means proved that slates are never metamorphosed into gneiss. But the facts detailed by Mr. Lydekker do not necessitate this conclusion; he confessedly does not distinguish between the true central gneiss and the gneissose granite, both are indicated by the same colour on the map and described together in the same chapter without being specifically distinguished,[2] and what he has described as partial metamorphism of the Panjál rocks into gneiss seems to be more properly described as intrusions of gneissose granite in the Panjál slates. The error is one which, owing to the tendency of the granite to be intruded in sheets parallel with the bedding and the highly foliated structure it usually assumes under those circumstances, has been fallen into by more than one observer previous to Mr. Lydekker.

"Panjál system."

The Panjál system is used as a generic term for "all the rocks below the Kuling series, and above the metamorphics." As might be expected from this comprehensive definition, the different sections

[1] Mem. Geol. Surv. Ind., XXII, (1883).
[2] Mem. Geol. Surv. Ind., XXII, chap. IX.

described vary widely among themselves. What may be called the type section, that across the Pir Panjál range is described as consisting of—

1. Greenish slates and sandstones with amygdaloidal traps.
2. Black and green slates with thick beds of conglomerate, containing pebbles of quartzite and slate.
3. Whitish quartzites and sandstones.
4. Black schisty slates with pebbles of gneiss and quartzite.[1]

It is further stated that "the resemblance of some of the rocks of No. 2 to the lower division of the Blaini series, both petrologically and stratigraphically, cannot fail to be noticed:"[2]

Panjal traps.

The volcanic beds No. 1 are largely developed in Kashmir and Mr. Lydekker is probably right for the most part in classing them all of one age. The occurrence of volcanic beds at two distinct horizons in the Simla region does not necessitate both of them being represented in Kashmir, and the only indication of two distinct volcanic series that I can find is in the description of the section on the road from Kashmir to the Kishenganga valley over the Tútmári pass where the volcanics are said to occur at a lower horizon than in the Kashmir valley.[3]

In the neighbourhood of the Kashmir valley there is a perfect conformity between these traps of the "Panjal system" and the overlying Kuling series at the base of the "Zánskár system," or to speak more correctly, the volcanic outbursts continued well into the Kuling period.[4]

Kuling series.

The rocks of the Kuling series consist of limestone quartzite and shale or slate, the former appears to be more abundant in the Kashmir valley than elsewhere, while the latter is often impregnated with carbonaceous matter like the slates of the carbonaceous series in the Simla region. It has yielded a series of fossils, limited in number, but still enough to fix its homotaxis with the lower Carboniferous rocks of Europe.

Probable unconformity above the Kuling.

The conformity between the Kuling and supra-Kuling series appears to have been assumed rather than proved; indeed, Mr. Lydekker's description has several passages which point to the opposite conclusion. The supra-Kuling beds are described as resting, at more than one point directly on the Panjal traps without the intervention of the Kuling beds, but in respect to this he says that wherever it occurs he has concluded that "the Kuling series has been included in the trappean rocks and cannot consequently be recognised as a distinct formation."[5] But it is equally open to conclude that it indicates an unconformity, and this conclusion is supported by the fact that both in Spiti and in Hundes an uncomformable break occurs between the Carboniferous and Triassic beds.

Supra-Kuling.

The supra-Kuling beds of Kashmir appear to consist almost entirely of massive limestone and dolomite which have yielded some fossils, for the most part, unfortunately undeterminable specifically

[1] Mem. Geol. Surv. Ind., XXII, 216.
[2] Similar beds occur in an analogous position below the volcanic beds in the Sind valley and on the slopes of the Hóksar range east of the Kashmir valley.
[3] Mem. Geol. Surv. Ind., XXII, 225.
[4] " " " " " 135.
[5] " " " " " 148.

but indicating the triassic age of the lower portion of the series. It is very probable that on more detailed examination this series will have to be split up into more than one and will certainly be sub-divided into groups.

With the third sub-division, or Chikkim series, which is represented only by a couple of isolated patches, we have no present concern.

From the above it appears that Mr. Lydekker's division of the beds above the gneiss, into two systems, is not a natural one and it is extremely probable that a more detailed examination of the country will result in an amplification of the sequence similar to that which has taken place in the Simla-Himalayas.

Carbonaceous system represented.

One point, however, seems clear, that there is in the Kashmir area a conformable series of beds charactized by the occurrence of: (1) boulder-bearing slates of non-volcanic origin, (2) at a higher horizon copious indications of contemporaneous volcanic activity, and (3) the occurrence of beds remarkable for the prevalence of carbonaceous matter. The similarity between the boulder slates and those of the Blaini group in the Simla-Himalayas has been especially remarked, and similar beds are found in the intermediate country of Chamba; while the resemblance between the volcanics of Cashmere, of Chamba, and of the Sutlej valley, the last of which belongs to the carbonaceous series, has been remarked upon by Colonel McMahon.[1]

These coincidences can hardly be all of them fortuitous and the conviction naturally forces itself upon one that the series of rocks referred to above is the equivalent of the carbonaceous series in the Simla-Himalayas; and the conclusion becomes irresistable when we compare the latter with the Kuling series in Spiti.

Kuling series of Spiti.

The series of rocks named Kuling by Dr. Stoliczka[2] is exposed in the only localities that have been visited as yet, at the bottom of a valley: the whole thickness is not seen and they are moreover very much disturbed. The beds, however, consist of quartzites and black carbonaceous slates similar to those of the carbonaceous series, and at two spots in the Spiti valley pebble-bearing slates, precisely similar to those of the Blaini group have been found, one of these being certainly among the Kuling beds. No beds of volcanic origin have been found but this may only be due to the imperfect exposure of the section.

Here, again, the coincidences can hardly be entirely fortuitous and we are justified in accepting Dr. Stoliczka's identification of these beds with the carbonaceous, or as they were then styled Infra-Krol, beds of the Simla area. In a similar manner the Kuling beds of Spiti and Kashmir might be safely correlated on the ground of their physical characters alone; but in this case we have the confirmatory evidence of fossils, four out of the seven species found in Spiti having also been found in the Kuling group in Kashmir.[3]

[1] McMahon. Rec. Geol. Surv. Ind., XVIII., 97, 98, and XIX, 68.

[2] Mem. Geol. Surv. Ind., V, pt. i.

[3] The three localities mentioned in the text probably do not by any means indicate the limits of the area over which the carbonaceous system maintans its uniformity. In the neighbourhoed of Naini Tal carbonaceous slates, conglomeratic slates and volcanic beds, are developed largely, and will probably prove to belong to a single system when fully examined.

Homotaxis of the carbonaceous system.

Having established the presence of beds belonging to the carbonaceous system in Kashmir and Spiti, we may now proceed to the consideration of the homotaxis indicated by the fossils that have been found in these districts.

Classed as lower Carboniferous, but probably newer.

The fauna[1] comprises 46 species in all, of which 17 are also found in the lower Carboniferous of Europe, 12 in the marine Carboniferous beds of Australia, and 16 in the Productus limestone of the Salt-Range. From the above it has been concluded that the genaral homotaxis is with the lower Carboniferous beds of Europe; but there are good reasons for considering the beds as newer than this.

In the first place the relationship of the fauna to that of the Productus limestone is close though not sufficient to establish contemporaneity considering the small intervening distance; moreover, the identities being among the more characteristically palæozoic forms of the Productus limestone fauna is compatible with an earlier date of formation. On the other hand, the Productus limestone of the Salt-Range is, like the Kuling group of Kashmir, underlaid by a conformable sequence of beds at the base of which occur boulder shales of generally acknowledged glacial origin. These doubtless are the equivalents of the boulder-bearing slates of Kashmir and Simla and of contemporaneous origin with the latter. In view of this, and of the known variations in the marine fauna of neighbouring localities due to variations of environment, I think far greater weight should be attached to the similarity than to the differences between the two faunas and they may consequently be regarded as homotaxial, if not of contemporaneous origin. In this case the age should be determined by the more extensive fauna, that of the Productus limestone, which has been regarded by Dr. Waagen as of Permian age, a date which, in view of the presence of so typically mesozoic forms as *Ammonites*, we may safely regard as the oldest admissible date.

Further evidence pointing to the same conclusion is the occurrence in the glacial beds below the Productus limestone of fossiliferous pebbles[2] of derivative origin which have yielded a limited fauna closely allied, so far as it goes to that of the marine Carboniferous beds of Australia. There can be little doubt that the beds, from which these fossiliferous pebbles are derived, are the equivalent of the Tálchir group in the Peninsular area, and I have elesewhere given my reasons for regarding the latter as the equivalent of the marine Carboniferous beds of Australia, and not as the Salt Range pebbles would indicate of later age. The Tálchirs, I need hardly add, are now generally regarded as of uppermost palæozoic, probably Permian age.

From the above it will be seen that the fauna of the Kuling group can be made to indicate a homotaxis anywhere between the lower Carboniferous and Permian horizons of Europe. This is a good instance of the limits of error necessarily attaching to the palæontological method when applied over long distances; but enables us to arrive at the conclusion that the carbonaceous system of the Hima-

[1] See Lydekker. *Mem. Geol. Surv. Ind.*, XXII, 158.

[2] The strictly pebbly condition is open to question, see R. G. S. of I., XX, 118, and Dr. Waagen's Essay on "The Carboniferous Glacial Period," in present number, p. 118, which should be read in connection with the whole of this paragraph.—*Ed.*

layas was deposited during the latter end of the palæozoic period, and corresponds to part, if not the whole, of the Carboniferous and Permian eras.

The Jaonsár system.

The only other system which I can correlate with any degree of certainty is the Jaonsár system, the lower group of which is probably represented by the middle division of the Babeh series of Dr. Stoliczka. The lithological resemblance of the groups is most striking and though no volcanic beds are seen in the Babeh pass section they are described by Dr. Stoliczka as occurring in Lower Spiti.

Equivalent to Vindhyan.

In the Peninsular area it may be represented by the Vindhyan system, the rocks of which would, if more indurated and disturbed, resemble those of the Jaonsár system. A further piece of evidence though not at present of great value, is the occurrence of beds of possibly glacial origin at the base of the Jaonsár system and the occurrence of beds containing large boulders imbedded in a fine-grained matrix among the Vindhyan beds east of the Aravalis, and the occurrence of similar beds at the base of a series of rocks, occurring west of the Aravalis, which have been, with little or no hesitation, classed as Vindhyan by every observer who has examined them.

Of Silurian age.

This correlation would give the Jaonsár and Vindhyan systems an age corresponding at the latest to part of the Silurian system of Europe,—a correlation, so far as the Vindhyans are concerned, in accordance with that adopted by the authors of the Manual, though at variance with that suggested by Mr. Griesbach.[1] This latter, however, is even more conjectural in its basis than that which I have offered, and, moreover, does not appear to allow sufficient time for the enormous unconformity between the Vindhyans and the Gondwanas of the Peninsula.

Other systems.

As regards the remaining systems of the Lower Himalayan sequence, it is impossible to do more than guess at their ages. The central gneiss is presumably of "Archæan" age, for the Deoban limestone I can find no equivalent among the fossiliferous beds of the Central Himalayas, while the Krol limestone is probably represented by part, which part cannot be determined, of the limestones which extend from Lower Trias to Lias in Spiti and Kashmir.

General conclusions.

The general conclusion we may arrive at is that throughout the whole of the Palæozoic and Mesozoic periods the area under consideration has been alternately land and sea, and that throughout this long period there appears to have been but little disturbance of the beds, in consequence of which there is a general parallelism of dip and unconformity can, as a rule, only be determined by overlap.

[1] Rec. Geol. Surv. Ind., XIII, 88.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1888. [November.

Notes on Indian Fossil Vertebrates, *by* R. LYDEKKER, B.A., F.G.S.

1. THE ULNA OF *Hyænarctos*.

Among a small collection of bones obtained by Mr. R. D. Oldham in the Siwaliks of Kasamúri Rao, Sahåranpur district, and lately sent to me by the Director of the Survey, the only specimen of any interest is (No. H $\frac{47}{8}$) the nearly entire right ulna of one of the species of *Hyænarctos*. Of this bone the proximal extremity is represented in the accompanying woodcut (fig. 1). In regard to the generic reference, it is quite clear that this specimen does not belong to the *Felidæ*; and the only other known Siwalik carnivore of sufficient size to which it could belong is *Hyænarctos*. The specimen agrees, moreover, with the imperfect ulna in the British Museum noticed in the 'Palæontologia Indica,' ser. 10, vol. II, p. 225, which was probably associated with the type skull of *H. sivalensis*; and since it closely resembles the corresponding bone of *Amphicyon*, its reference to *Hyænarctos* may be considered certain.

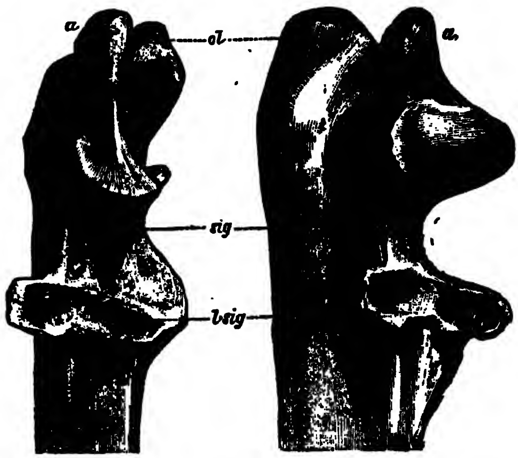


Fig. 1. Palmar and preaxial aspects of the proximal extremity of the right ulna of *Hyænarctos*; from the Siwaliks of the Sahåranpur district: ½ nat. size. *ol.*, olecranon; *a*, anterior tuberosity of do.; *sig.*, greater sigmoid cavity; *l. sig.*, lesser sigmoid cavity for head of radius.

In the above-mentioned ulna the proximal extremity is wanting; and since there is

great variation in this part among the different genera of Urso-Canoids, some important conclusions may be drawn therefrom as to the affinities of *Hyænarctos*. It will be observed from the figure that the olecranon is well developed, ascending a considerable distance above the proximal portion of the greater sigmoid cavity for the articulation of the humerus, and possessing a strongly-marked anterior tuberosity. The lesser sigmoid cavity is deeply concave, and indicates free supination of the manus. Compared with the ulna of *Amphicyon* figured by Dr. Filhol in the 'Ann. Sci. Géol.,' vol. X, pl. XIV, fig. 3, the resemblance is so close that in the absence of other evidence the two specimens might well be referred to the same genus. In the ulna of *Canis* the well-developed olecranon is retained, but the lesser sigmoid cavity becomes much flatter and less well defined in correlation with the greatly diminished power of supination of the manus. Turning, however, to the ulna of *Ursus* (fig. 2), we find a wide difference from our specimen, owing to the abortion of the olecranon and the almost total disappearance of its anterior tuberosity. A very similar condition of the olecranon obtains in the Primates, and is, I presume, connected with the power of straightening the fore arm on the upper arm.

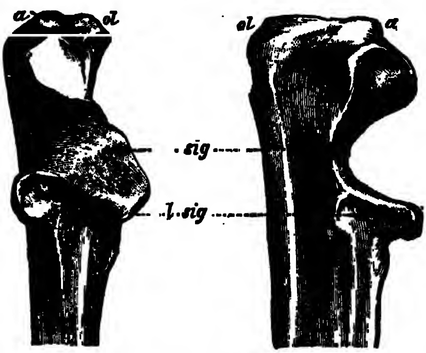


Fig. 2. Palmar and preaxial aspects of the proximal extremity of the right ulna of *Ursus arctos* : ½ nat. size. Letters, as in fig. 1.

In my description of the skull of *Hyænarctos* in the 'Palæontologia Indica' already cited, the conclusion was reached that this genus might be regarded as connecting *Amphicyon* with *Ursus* through the intervention of the American *Arctotherium*. This conclusion receives support from the present specimen, which (as is the case with the carnassial teeth) is nearer to the corresponding element of *Amphicyon* than to that of *Ursus;* and I conclude that the humerus was in all probability furnished with an epicondylar foramen, as in the former genus. In *Arctotherium*, which displays a dentition much more like that of *Ursus*, the olecranon has become aborted after the Ursine type.

Finally, I may observe that on page 239 of the above-quoted memoir I expressed an opinion that the dentition of *Hyænarctos* was more specialized than that of the Bears. This opinion I now withdraw, and, in accordance with the views of Professor Flower, I look upon the Bears as the most specialized members of this branch of the Urso-Canoid stock; which have, however, to suit their fissorial and scansorial habits, retained the primitive pentedactylate and plantigrade feet.

2. *Massospondylus*, FROM THE KAROO AND GONDWANA SYSTEMS.

In my memoir on the 'Reptilia and Amphibia of the Maleri and Denwa Groups' published in the 'Palæontologia Indica,' ser. 4, vol. i, pt. 5 (1885), I described (pp. 26–29) and figured certain Reptilian remains from the Maleri beds which I regarded

as Dinosaurian, and placed in the neighbourhood of the English Triassic genus *Thecodontosaurus;* following the lead of Professor Huxley in classing the latter with *Scelidosaurus* and its allies. I thought it, however, advisable to refrain from giving a generic name. These remains comprise one extremity of the centrum of a dorsal or lumbar vertebra (pl. V, fig. 4), a caudal vertebra (*ibid.*, fig. 7), some phalangeals (pl. IV, figs. 7, 8), and teeth (pl. VI, fig. 10, and woodcut fig. 1, p. 29). The vertebræ are amphicœlous, with long, laterally-compressed centra, having oval terminal faces, and the upper surface deeply excavated by the base of the neural canal. The phalangeals resemble those of the Ornithopoda and Theropoda; while the teeth come nearest to those of the European *Thecodontosaurus* and the North American Triassic *Anchisaurus* (*Amphisaurus*); these two genera being placed by Professor Marsh in a single family of the *Theropoda* under the name of *Anchisauridæ.*

During a recent visit to the Museum of the Royal College of Surgeons I was struck with the resemblance to the above-mentioned specimens presented by a series of Reptilian bones collected many years ago from the Karoo system near the town of Harrismith, in the Drakenberg range, Basutoland. These specimens are catalogued by Sir R. Owen in the 'Catalogue of Fossil Reptilia,' pp. 97, 99 (1854), under the names of *Massospondylus* and *Pachyspondylus;* caudal vertebræ being taken as the types of the two genera. The bones are coated with a hard ferruginous matrix, and are indistinguishable as to mineralogical condition from Maleri specimens.

It will be unnecessary on this occasion to discuss the question whether there are really two genera among these South African specimens; and it will be convenient to refer to the dorsal vertebræ and limb-bones under the name of *Massospondylus,* since there is at least an equal probability of their belonging to this genus rather than to *Pachyspondylus.* The specimens comprise, in addition to the caudals, several centra of trunk vertebræ, an ilium, and numerous phalangeals of the manus and pes. In the original notice it was stated that some of these remains showed Dinosaurian affinities, but their ordinal position was left an open question.

With our present knowledge of the structure of the Dinosauria it is at once apparent that these African bones are referable not only to that order but to the sub-order Theropoda. Thus the ilium, which belongs to a small individual, is of the general type of that of *Megalosaurus,* although presenting well-marked generic differences. The

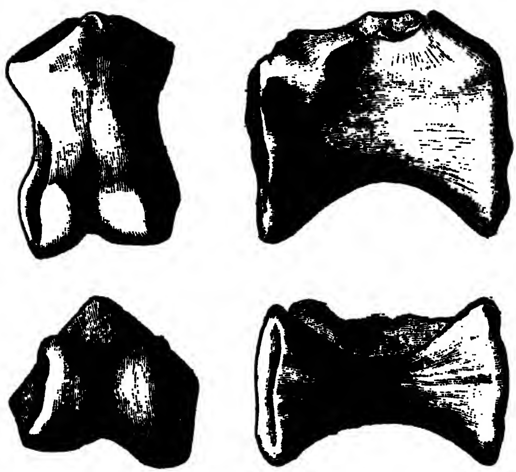


Fig. 3. Dorsal and distal aspects of a phalangeal of the manus, nat. size; and lateral and hœmal aspects of the centrum of a trunk vertebra, ½ nat. size, of *Massospondylus carinatus;* from the Karoo system of Basutoland.

characteristic sharply-curved terminal phalangeals of the manus are also decisive as to the subordinal position. In the trunk vertebræ, of which one specimen (No. 336) is represented in the accompanying woodcut, the centrum is much constricted laterally and excavated inferiorly, with oval and amphicœlous terminal faces, after the manner of the dorsals of *Megalosaurus*. Certainty is added to this resemblance by the presence of a fusiform median cavity in the centrum, as is demonstrated by a transverse fracture now cemented together. One of the second or third phalangeals of the manus (No. 380) is shewn by the side of the vertebra in fig. 3.

The special interest of these specimens lies, however, in their close resemblance to the above-mentioned Dinosaurian bones from Maleri. The vertebra figured in the accompanying woodcut, except for its smaller size, cannot indeed be distinguished from the Maleri specimen shewn in pl. V, fig. 4 of my memoir; while the figured African phalangeal of the manus agrees in all respects with the larger Indian phalangeal of the pes represented in pl. IV, fig. 8. It is true, indeed, that these resemblances are insufficient to indicate with absolute certainty the generic identity of the Indian with the African form, yet when we bear in mind the occurrence of generically identical Dicynodonts in the Gondwana and Karoo systems, the extraordinary similarity to one another presented by those two series of deposits, and the absolute identity in the mineral condition of the African and Indian specimens under consideration, I venture to think that we may be justified in referring the latter to the African genus. Accepting this reference, important evidence is afforded by the Maleri teeth as to the relationship of *Massospondylus* with the *Anchisauridæ*, to which family it may, I think, be pretty safely referred. I am not, indeed, in a position to say whether the Old World genus is really distinct from *Anchisaurus*; but if the latter is unknown in Europe its appearance in India would be very unlikely. The original notice of *Massospondylus carinatus* is too incomplete to allow of the name being regarded as more than a manuscript one; and, if such a course be permissible, I would suggest that it might date from the present description, with the figured specimens as the types.

The matrix of the African specimens of *Massospondylus* being different from that in which the African Dicynodonts are found may be taken as fair evidence of a distinct geological horizon; and since the occurrence of Dicynodonts in the Panchet stage of the Gondwanas indicates the probability of these beds being the equivalents of those which yield the same family in Africa, it is probable that the Harrismith beds yielding *Massospondylus* are the equivalents of the Maleri stage, which is considerably higher than the Panchets.

In conclusion, I may express my thanks to Professor Stewart, Conservator of the Royal College of Surgeons, for permission to describe the African specimens.

Some Notes on the Geology *of the* North-West Himalayas; *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

SPITI.

The observations on which the following remarks are based were made during a tour, through Ladak and Kashmir, undertaken with a view to determining how far the discrepancies between the sequence of beds in Kashmir, as described by Mr. Lydekker, and that of the Simla region was real. As the country traversed has, with a small exception, already been examined cursorily by previous observers, I shall only notice those points on which I find it necessary to differ from or amplify opinions already recorded.

The first exposure of gneissose granite seen was on the road between Narkanda and Kotgarh at about one mile before the road to Kotgarh branches off from the old Hindustan and Thibet road. This exposure is apparently a continuation of the lower of the two exposures on the Hattu ridge, recorded by Colonel McMahon, but, owing to the density of the forest, the two could not be traced into continuity. Colonel McMahon has expressed an opinion, based on the microscopical characters of the rock, that these exposures must be regarded as metamorphic gneiss, not granite. I find myself unable to agree with this opinion, for not only do both bands occur among schists and bacillary quartzites undistinguishable from those of the Boileauganj Hill and like them associated with black carbonaceous slates, but in the exposure on the summit of Hattu I saw several well-defined crystals of orthoclase lying with their longer axes more or less transverse to the planes of foliation. Mineralogically the rock is a gneiss, and in the lower exposure the porphyritic crystals of felspar have lost their crystalline outline and form mere lenticular eyes, so that both macroscopically and microscopically the rock might well pass for gneiss did not its association preclude the idea.

But this loss of the characteristics of an intrusive rock is not nearly so marked as in an exposure on the old road from Kotgarh down to the Sutlej. Here, above the village of Shaot,[1] there is what looks like highly-foliated mica schist, with little or no quartz but occasional specks of felspar. For the most part the rock is very soft, but there are occasional harder bands which, owing to a larger proportion of felspar and quartz, have resisted decomposition. On breaking open a block of the micaceous rock the felspar is seen to be in larger proportion than appears on the weathered surface, as each speck is but the termination of a rod of felspathic material devoid of definite crystalline structure. The rock occurs among carbonaceous slates and quartzites of the type of the Infra Krol groups of Mr Medlicott, and can hardly be ascribed to a metamorphism of part of these beds *in situ*, while the drawing out of the felspathic material into strings is probably due to fluxion while the rock was in a plastic condition. If this conclusion be correct the rock is an extremely impure representative of the gneissose granite, several other exposures of which, all highly micaceous, though not so much so as this one, occur lower down the same spur.

[1] Situated on the spur between Súlan (Súilán) and Kété (Rita).

Along the Sutlej valley exposures of gneissose granite are common and have already been recorded by Colonel McMahon; they are all shewn to be granite by the occasional occurrence of definite crystals of orthoclase lying more or less transverse to the foliation planes. These crystals become more numerous and conspicuous towards the east; in other words the further the intrusions are traced from their eastern source the more do the originally well-formed orthoclase crystals lose their crystalline form and become degraded into rounded lumps of felspar.

Rocks of the Sutlej Valley.—With the exception of the gneissose granite, some true gneiss seen on the last two marches and the diorite intrusions described by Colonel McMahon,[1] the rocks between Kotgarh and the Wangtu bridge are of volcanic origin, carbonaceous slates, white quartzites similar to those of Bawar and other less characteristic beds belonging to the same series which I have proposed to call Carbonaceous. Two interpretations of the section have been given on different occasions by Colonel McMahon, but beyond expressing an opinion that both require extensive modification I shall add nothing to what has been written above. All conjectural interpretations of Himalayan sections, not based on extended survey, are in the last degree hazardous, especially where, as in the present case, the section is carried almost along the strike of the beds.

Central Gneiss of Wangar Valley.—I have already incidentally mentioned the occurrence of true gneiss south of the Sutlej valley, but the series is much better exposed on the ascent from Wangtu bridge to the Sutlej valley. At the bridge itself oligoclase granite is *in situ*, as has been abundantly described by previous observers, but on the ascent it soon gives way to gneiss. I have nothing here to add to the late Dr. Stoliczka's description but to say that it is most indubitably a gneiss series and as distinct as can be from the intrusive gneissose granite. Occasionally specimens are so highly granitoid that the foliation has disappeared, but the occurrence of well-defined beds, arranged parallel to each other and differing in lithological structure and mineralogical composition, shew that the series must have originated by sedimentation or some analogous process. The junction of the gneiss and slate series of the Babeh pass is marked by an intrusion of the gneissose granite; and nothing could be more distinct than the porphyritic granite devoid of stratification, with its defined crystals of felspar lying without any definite orientation, and its numerous inclusions, whether of foreign rock or formed by greater local concentration of the micaceous element on the one hand, and the distinctly stratified gneiss, often granitic, not infrequently porphyritic but with the porphyritic felspar, whether crystalline or in the form of lenticular eyes, lying parallel with the foliation, planes on the other.

Babeh Pass and Spiti section.—I have little to add to Dr. Stoliczka's description of this, and nothing to modify except as regards the lower portion.

The lowest beds, or slate group of the Babeh series, contain some bands of carbonaceous slate which render it probable that they may be brought into their present position by disturbance. The upper beds of the series, consisting of red quartzites resemble very strongly the quartzites of Chakrata, even to the occurrence of fragments of serpentinous rock and occasionally a film of serpentine on the bedding planes, as is not uncommon among the 'Lower Chakratas' of N. E. Jaonsar.

[1] Rec. G. S. of I., X, 214, *et seq.*; XII, 65, *et seq.* and 75, *et seq.*

Above these quartzites are some black carbonaceous slates, slightly schistose and shewing a sheen on the foliation surfaces, very common among the 'Infra Krols' of the Simla area. It is not impossible that the upper and lower groups of Stoliczka's Babeh series may be the same, and that instead of a regularly ascending section there is a very much compressed anticlinal. However, beyond the occurrence of black carbonaceous slates there is nothing to support the supposition; I could not recognize the slates on either side of the quartzite as belonging to the same group.

The Muth series of Stoliczka resembles nothing I am acquainted with in the Simla area. One thing I feel certain of, that it does not represent the Blaini group of Simla; the conglomerates of the Muth series are perfectly ordinary conglomerates and quite different to the very peculiar Blaini rock. According to Dr. Stoliczka there is a transition between the Muth and Babeh series, the purple (red) beds at the base of the former being said to be interbedded with the green and grey slates and quartzite at the top of the former. I do not know how far this statement rests upon a direct observation, or how far it may depend on a distant view of the cliffs overhanging the left bank of the stream.[1] If only the latter, little weight can be attached to the observation, as fallen fragments shew that ther ed colouration of the bands interbedded in the grey beds is superficial, while the colour of the lower group of the Muth series extends through the rock.

The uppermost group of speckled and white quartzites so strongly resembles some of the quartzites of the Carboniferous series of Kashmir, and in a less degree of the Carbonaceous series of the Simla area, that one may be allowed to doubt whether they should not be ascribed to the Kuling series. This would make the Muth series Carboniferous, though the obscure fossils it has yielded were regarded by Dr. Stoliczka as Silurian. As none of these were specifically determinable, perhaps too great weight should not be allowed to this opinion.

The Kuling or Carboniferous rocks are not well exposed in Spiti; its apparently capricious appearance and relations to the other sedimentary groups support the opinion expressed by Dr. Stoliczka, that there was an unconformable break at the close of the Carboniferous period. The lithological resemblance of the beds to those of the carbonaceous series of the Simla area is striking, and at two spots in the Spiti valley a rock occurs which resembles in structure the Blaini conglomeratic slate. The first or easternmost of these is associated with beds believed by Colonel McMahon[2] to belong to the Carboniferous or Kuling group: in this I agree with him though no great certainty attaches to the identification. But in the case of the second exposure there can be no doubt whatever that the beds among which it occurs are of Kuling age.

The similarity of the rocks of the Kuling and Carbonaceous series of itself suggested to Dr. Stoliczka the probability of their being the same, and when we find beds, like the conglomeratic and carbonaceous slates, both of which, and especially the former, point to special and unusual conditions of deposition, common to the two, this suggestion acquires a degree of probability which closely approaches a certainty.

[1] Dr. toliczka's route lay along the right bank.

[2] Rec. G. S. of I., XII, p. 63.

Recent and Glacial Deposits of the Babeh Pass.—One of the most striking features noticeable on this route is the marked absence of distinct traces of glaciers south of the pass and their conspicuousness north of it. The valley of the Wangar is straight and open, and without interlocking spurs—a feature often regarded as characteristic of glacier action. But as the valley has been filled to some hundreds of feet with recent river gravels which have been largely re-excavated by the stream this feature is not conclusive: for once deposition begins to take place in a rocky valley the stream is no longer confined to one channel but is free to wander over the gravelly bottom of the valley and impinge on one spur after the other, gradually cutting away their extremities and so forming a straight and open valley. This may be seen everywhere in the Himalayas where a stream is flowing in a gravelly bottom; often the oldstraight valley with its floor of deposition can be traced, while at a lower level the stream flows in a narrow tortuous channel with interlocking spurs.

The mere openness of the valley is not, therefore, by itself a proof of its having been filled by a glacier. Nor are any moraines seen south of the pass, though there are several landslips which might pass for moraines. The first of these forms a pine-clad barrier stretching across the valley immediately below the summer grazing ground of Muling. In form it resembles a moraine, but it contains no fragments of the slate which forms all the hills at the head of the valley, while immediately above it is a recent landslip repeating its features on a smaller scale. This landslip, which was said to have fallen last year, extended across the river channel and evidently for a time dammed it back as the barrier has been breached, leaving a portion of the landslip separated from its source by the river channel. Although breached it has not been without influence on the river, for above it the spread-out shallow course of the stream and the partially buried trees shew that the gradient has been checked and that deposition is taking place.

Further up-stream there is again what might be mistaken for a moraine were it not that the deposit consists entirely of blocks of porphyritic granite fallen from above; while there is not a single block of the slate which commences a mile higher up and extends to the watershed.

Above Portirang, whence the track strikes up from the valley to cross the Babeh pass, there is another old landslip, and above it a plain of sand and fine gravel which seems to occupy the position of a former lakelet dammed by the landslip.

From Portirang the path ascends a steep slope of débris, and here we first come upon an indubitable moraine, for this slope is that of the moraine of a small glacier which, descending from the pass, rode out into the valley over its own moraine.

North of the pass there is a landslip just above Práda;[1] and at Práda a hummocky grass-clad surface which appears to be a moraine. Lower down, the valley broadens out, and at Baldar there is a perfectly preserved moraine stretching across the valley in a crescent, convex down-stream.

Below Baldar the bottom of the valley is occupied by river deposits of rounded

[1] This is Baldar of the map; Baldar, misprinted Balair in Dr. Stoliczka's memoir, p. 18, is further down, at the junction of the first considerable stream from the east.

gravel, but over these a glacier must have travelled, for less than a mile above Múth there are the remains of an old moraine resting on the river gravels.

We have consequently distinct traces of glaciers having extended on the north side of the pass to a distance of 3,000 feet below and 17 miles from the crest; while on the south side no certain traces can be found more than 1,000 feet below and about ½ mile from the crest.

This difference is paralleled by the present distribution of ice; south of the pass there is said to be a small glacier; I was not able to determine its extent as the whole country was covered with snow, but it cannot extend for more than a ¼ mile. To the north, on the contrary, the descent leads for over 2,000 feet and 2½ miles over the Babeh glacier. The contrast is doubtless due to the fact that the waste is much less on the north than on the south side of the pass; not only from the intensity of the sunshine being less, but to a much larger extent owing to the comparative absence of rain, little of which falls north of the pass, while there is probably a much less proportional difference in the snowfall.

Recent Deposits of the Spiti Valley.—In the valley of the Spiti recent deposits are largely developed and extend high up the N. E. side of the valley. It is noteworthy that the slope of the obscure bedding in some of these shews them to be portions of talus fans which came from the S. W., so that it becomes clear that as the Spiti river excavated its course in the neighbourhood of Dhankar it worked out a channel lying S. W. of its original one.

It is evident from an examination of these deposits that the Spiti river has seen many vicissitudes and has frequently changed from erosion to deposition and *vice versá.* At one time its valley for many a mile was occupied by a lake whose only vestiges now are whitened cliffs of fine laminated clay which can be seen at intervals from near the bridge at Mani to near Lára, a distance of 9 or 10 miles. The stuff is fine and clayey; on the surface it weathers pale yellowish-white, but inside it is of a grey colour; where not covered by rain-wash it may be seen to be finely stratified; near the sides of the valley strings of angular gravel tail off into it, while everywhere small pebbles are to be found though rarely; in composition it consists largely of finely comminuted limestone, in consequence of which it effervesces freely with acid and a large proportion is dissolved. From these facts it is not difficult to conclude that the stuff is mainly if not entirely glacier-mud which has been deposited in a lake.

LADAK AND KASHMIR.

Gneissose and Granitic Rocks of Rupshu and Ladak.—These have been referred to by both Mr. Lydekker and Dr. Stoliczka, but as neither distinguished between gneiss and granite their descriptions leave much to be desired.

The rocks on the shores of the Tso Morari are not gneiss as marked on Mr. Lydekker's map but slates mostly somewhat schistose and limestones. Among these there is an intrusion of gneissose granite which sends off many veins running through and among the slates; this is the southern of the two exposures of gneiss mentioned by Dr. Stoliczka on p. 127 of his memoir.

North of the Tso Morari the slates &c. are unconformably underlaid by a true gneiss series, distinctly stratified, with the foliation parallel to the stratification, which extends to the southern boundary of the Indus Valley Tertiaries.

The next exposure seen belonged to the Ladak range. This rock I saw on the pass between Maya and Shushul, again on the Chang La and along the north bank of the Indus from Ladak to near Nurla. Everywhere the rock was a syenite, on the Chang La micaceous, shewing no signs of stratification or foliation. Mr. Lydekker has described it to the west of Leh as having a dip to N. E.; all I could detect was a parallel system of joints dipping in that direction, but there was no division of the rock into bands differing from each other in composition. On the contrary it presents all the characters of an igneous rock, meaning thereby a rock which has solidified from a fluid condition. Inclusions of finer-grained rock differing in composition from the main mass are frequent, but besides this there are great variations in the composition of the rock: large masses of highly hornblendic rock ramify through the syenite and intrusions are frequent.

The whole mass so far as its composition goes might be intrusive, but if so the intrusion was of long pre-tertiary date, for the bottom beds of the tertiaries rest on an eroded surface of the syenite, indicating a lapse of time sufficient for the removal of the vast thickness of rock that once overlaid the syenite. Whether the latter is Archæan or no older than the granite intrusions of the outer hills I am unable to say.

The high range south of the Pangong lake, where crossed by the road from Shushal, consists of gneiss with intrusive veins of gneissose granite.

Finally the Tertiaries at Khargil rest on an unfoliated granitic rock containing hornblende, whose relation to the Tertiaries is the same as that of the Ladak range.

The Indus Valley Tertiaries.—As these have already been described by Mr. Lydekker more fully than I could do, I shall confine myself to considering the conclusions that may be drawn from them.

To begin with the serpentine rocks: both Dr. Stoliczka and Mr. Lydekker speak with uncertain voice regarding their mode of origin, but both convey the impression that they form a large intrusive mass, though in both descriptions there are not wanting indications that the authors did not altogether accept this conclusion.

I crossed these rocks once on the section from Puga to Maya and again between Leh and Kashmir. In both cases I found beds of clastic origin, ashes and agglomerates interstratified with traps. To take the first-named section: starting from Puga the first rock seen, after leaving the gneiss, is a serpentinous slate; this is succeeded by a conglomerate or breccia of slate and limestone, the fragments all flattened by pressure and traversed by an imperfect cleavage, and fine-grained laminated beds with fragments of rock included. The matrix of these rocks contains many small fragments of pyroxene. Further on the volcanic facies becomes more marked and we have tuff and ashes with dense pyroxenic traps, all of which have undergone more or less complete serpentinous change.

Where the stream bends to the east the dip of the beds, which had been northwards, changes to south but is very obscure. At the bend of the stream a bed of limestone occurs among the volcanics but is cut up by faults into small patches of a few yards across scattered up and down the hill side in a most perplexing manner, and this intense cutting up of the beds is sufficient to account for the absence of distinct and continuous bedding in the traps.

As to the interpretation of the section, it would at first appear that from Puga to the bend in the stream there was an ascending and below that a descending sec-

tion; the crystalline limestone occupying the centre of a synclinal. But lower down-stream this same limestone occurs on the hills south of the valley above the dense traps, and to judge by the fragments brought down by streams, is overlaid by beds very like those seen in contact with the gneiss.

On the section along the Kashmir road these features are not so well seen, but even there ash-beds can be found among the traps. So there can be but little doubt that we have here a true volcanic series.

I must not be misunderstood to deny the existence of intrusive rocks; I have myself seen these some miles south of Karzók on the Tso Morari and as far north as Shushal. Intrusive rocks doubtless occur among the volcanics,—indeed this is but what might be expected and may doubtless account for the ambiguity in the two published descriptions.

As to the lithology of the beds, beyond what is implied in the above passages, nothing need be added to the descriptions of Dr. Stoliczka, Mr. Lydekker, and later, of Colonel McMahon.

I must next consider the supposed evidences of glacial action exhibited by the lowermost beds in the Indus valley. As described by Mr. Lydekker the sandstones contain boulders of gneiss often several feet in diameter. "Some of the isolated boulders shew the beds of the sandstone bending down below them; and the polishing and smoothing of some of the others seems suggestive of ice action."

So far as my observations go I saw no blocks smoothed and striated in the manner characteristic of glacial action; nor did I see any case of the bedding of the sandstones being bent down under the blocks, though the bedding in their neighbourhood sometimes shewed a disturbance evidently due to eddies caused by the boulder, and except for the size of many of the blocks there is no necessity to invoke glacial action. But among these sandstones there are many thick banks of angular blocks of stone ranging to many feet across and shewing for the most part a sharp angular outline. They must consequently have been derived from the immediate neighbourhood or else transported by some agency—such as floating ice —that would not expose them to abrasion. Now in these banks only a very small proportion of the fragments consists of the syenite of the Ladak range, while the bulk of them are an intensely hard hornstone porphyry which has not been seen by me—or so far as I can find out by any other observer—in the Himalayas. It is precisely similar to the Maláni porphyries of Western Rajputana; and in Srinagur I was shewn some pieces of a similar stone said to have come from Badakshan.

Besides this indication of glacial agency there may be mentioned the presence of undecomposed felspar, doubtless derived from the crystalline rocks of the Ladak range on which the tertiary beds rest, in the sandstones, some of the beds being principally composed of it.

In the Himalayas I have not found the crystalline rocks decomposing into sand containing fragments of undecomposed felspar at lower altitudes than 14,000 feet, and the very common association of undecomposed felspar with other indications of an extreme climate justifies us in looking on it by itself, as an indication of a cold climate. In the present case independent evidence is also available, and the occurrence of a glacial epoch at the close of the Cretaceous or early in the Eocene period may be looked upon as extremely probable if not actually proved.

Original extent of the Indus Tertiaries.—Both Dr. Stoliczka and Mr. Lydekker have regarded the present extent of these beds as marking very closely their original extension, but as the evidence appears to me hardly to support this conclusion, and as the question is one that has an important bearing on the theory of the Himalayas, it will be well to enquire into the matter more fully than has yet been done.

As regards the north-eastern and north western boundaries, they most distinctly mark the original limit of the lower beds of the series, for these can be seen to abut against the syenite of the Ladak range. On the south-west the beds have suffered much disturbance and the boundary is not one of original contact, so that there is no direct proof that the Tertiaries may not have extended far to the south. Nor does it follow, because the original extension of the lower group to the northwards is closely marked by its present limits, that the upper members of a series many thousands of feet in thickness were similarly limited in their extension.

With regard to the volcanic beds there are ample indications of a much larger area having been covered by them than is now the case. Not only are intrusive masses of pyroxenic trap, evidently of the same age as the Tertiary volcanics, found as far south as the Tso Morari and as far north as Shushal, but Mr. Lydekker has recorded the occurrence of a large outlier of the tertiary traps in central Zánskár;[1] this was not examined *in situ*, and it is uncertain whether they belong to the bedded volcanic series or are intrusive. If the former, their occurrence on beds of Jurassic age, without the intervention of the lower group of the Indus Tertiaries, would point to an overlap and limitation of the series in a southerly direction. But if the Zánskár outlier is intrusive, then it is probably only the core of one of the old Tertiary volcanoes.

From the above considerations it will follow that the supposed original limitation of the Tertiaries to the narrow region they now occupy is only proved in the case of the lowest group, and then only of the north-western and north-eastern boundaries; while as regards the south-western boundary and the volcanic group and the beds above it there are distinct indications of an original greater extension, and there is only negative evidence against their having been originally continuous with the Eocene beds of Chang-chengmo and the outer Himalayas.

Origin of the Rupshu Lakes.—It has been usual, since the publication of Mr. Drew's paper, to ascribe the origin of these lakes simply to the damming of river valleys by the fans of their tributaries. The barriers now visible are certainly talus fans, and these must extend to some depth below the former water-levels of the lakes; in some cases it may be that they form the entire barrier.

Yet it is not easy to understand how a lake could be formed in this manner; it would certainly be more natural to suppose that the main stream would be able to keep its channel open. There is however one way in which these lakes might be directly formed by talus dams and yet the ultimate cause be very different. If we suppose that any portion of a river valley were elevated more rapidly than the rate of erosion of the river,—a not very difficult supposition in so rainless a country,—the barrier so raised would react up stream and cause the formation of a sloping surface of river gravels. If then for some distance the configuration of the river valley was such that but little débris was shed into it and below this region the amount of débris

[1] Mem. G. S. of I., XXII, 116.

suddenly increased, it is quite conceivable that the rock barrier lower down might prevent this being carried away as fast as it was shed and so a talus dam formed across the valley.

There is one fact about the lakes which is difficult to reconcile with the theory that they are due to talus dams formed under climatic conditions differing from the present, and that is the very various degrees of dessication they present. The Hanle lake is now quite dry.[1] The Lingzitharig lake is almost dried up, the present area of permanent salt lake being less than one tenth of the original area. The salt lake of Rupshu occupies one eighth of its original extent,[2] the Pangong lake about one half, while the Tso Morari has contracted but one fifth and now has at least four fifths of its original extent.[3] Had the lakes all been formed at one period they would hardly exhibit these extreme variations in their degree of dessication, and this renders it more probable that some explanation such as I have proposed is the true one, as this would allow of the lakes having been formed at different periods, and of their consequent varying degrees of dessication.

Before leaving this subject it may be well to suggest that the gradual and progressive drying up of Ladak appears to me to have been a direct result of the gradual elevation of the Himalayas which in course of time cut off a larger and larger proportion of the moisture coming from the South.

Lake Basin and Karewahs of Kashmir.

The only two hypotheses which appear to have been suggested with regard to the orgin of the Kashmir Valley and more especially of the Karewahs are (1) that the dam was a glacier descending into the Jhelum valley, (2) a talus fan similar to the supposed barriers of the Rupshu lakes. The more obvious hypothesis that it was a rock barrier since cut through appears to have been regarded with but little favour.

In considering this question it is necessary to bear in mind that, though the largest and best known, Kashmir is not the only alluvial valley within the limits of the Himalayas. On the contrary it may be stated as a general rule that alluvial deposits of varying extent may be found in every river valley above where it enters what can be shown to be a region of special elevation. The only explanation of this peculiarity seems to be in the supposition that during the elevation of the Himalayas there have been times when the rocky bed of a river has been elevated more rapidly than it could erode its channel and thus a deposit formed above the barrier. A similar explanation I believe to be the true one in the case of Kashmir and the greater extent of the valley to be in part due to its drainage escaping across the junction of the Pir Panjal and Hagara systems of disturbance, a region which may well have been exposed to more repeated and extensive upheavals than other parts of the Himalayas.

The principal reason why other hypotheses have been adopted appears to be the supposed lacustrine origin of the Karewahs. This however I find to be extremely doubtful. In many places beds of indubitable lacustrine origin may be found among the Karewahs, but the bulk of them are plainly of subaerial origin; just as at the present day alluvium is being deposited subaerially over large areas in the valley,

[1] Mem. G. S. of I., V, p. 130.
[2] Drew; "Jummoo and Kashmir," p. 398.
[3] Op. cit., p. 305.

but here and there, in hollows left by irregularity of deposition of the alluvium, true lacustrine deposits are being formed. It seems probable that while nearly every part of the valley was at one time or another occupied by a sheet of water there never was at one time a lake extending over the whole area of the valley.

Geology of the road from Kashmir to Chamba.—This is the only part of my route which crossed entirely new ground and will consequently be described in greater detail than the rest.

Leaving the Noroboog valley I marched up the Rajpáran valley and crossed into the drainage area of the Wardwán by the Chingam pass. The rocks up to this belong to the "Panjal system" of Mr. Lydekker except near the pass where quartzites occur apparently belonging to the Kuling series, and about four miles west of the pass there is an exposure of pebble slate with black carbonaceous rock.

The head of the valley leading down to Shingam (Chingram) is excavated on an anticlinal. At the base are slates, and above these come quartzites interbedded with some black carbonaceous bands and volcanic beds. At one spot, in the second tributary stream flowing from the south, I was fortunate enough to obtain some fossils which have not yet been examined in detail but appear to be of Kuling age. It is noteworthy that here they occur well below the great development of the volcanic beds, unless there is a very complicated inversion on both sides of the valley of which I found no proof.

A curious feature may be observed near the head of this tributary. On the hill side there is a sudden step or bank, commencing gradually and reaching a height of about six to eight feet; it runs along the hill side with a general course to W. 15° N., coinciding with the strike of the beds, but V-ing to the south in the valleys. It crosses the head of the next tributary, and in two of the minor drainage depressions which are not large enough to have a defined stream-bed, it has formed small hollows in which water appears to rest after heavy rain. On the watershed between the Shingam and Rajparan drainages it appears as a sudden step on the ridge, rendered more conspicuous by a talus bare of vegetation which contrasts strongly with the grass-clad slopes on either side.

Westwards from the ridge it can be traced as a sudden step, or elevation on the down hill side, running across an old moraine deposit which once formed the bed of a glacier, and on this there is a small pond naturally dammed by the elevation. I was not able to trace the full extent of this feature owing to clouds but it appears to vanish about ½ mile west of the watershed.

The only cause to which I can ascribe this is the actual appearance of a fault at the surface. I have already noticed a much more conspicuous instance in the hills south of the Giri valley between old Sirmur and Nahan, but it may be noticed that in the present case the fault is a normal one, *i.e.*, it hades to the downthrow, while the Sirmur fault follows the almost invariable rule of Himalayan faults and is 'reversed.' The feature I have described is of recent origin as is shewn by the little effect that denudation has had on it, as well as by the manner in which it traverses what appears to be the bed of an old glacier. The fact that it has in one place been able to form a permanent pond points to the sudden origin of the feature, which probably accompanied one of the violent earthquakes which are known to have affected Kashmir in the past.

SAND-SCULPTURED QUARTZITE CONGLOMERATE, RAJPUTANA.

Descending the Shinton valley, slates continue with a high dip varying in direction between north and east, but towards Mogalmaidan they become schistose and garnetiferous, while all the streams leading down from the north contain boulders of gneissose granite.

From Mogalmaidan to Kishtwar mica and hornblende schists dip at high angles with a strike which has bent round to north and south, varying however up to 15° on either side, but usually not more than this.

Beyond Kishtwar a true gneiss series comes in suddenly, the junction with the schists being hidden by recent deposits. The gneiss has a general dip to south-west, and the Chenab flows along the strike and apparently close to the boundary between the gneiss and the overlying schists. In the Wariri valley a quantity of blue kyanite occurs in the gneiss by the road side and the same mineral is seen at intervals as far as Kandni.

Beyond Kandni the dip of the gneiss gets irregular and turns ultimately round to north-west. At the 'Khar gad,' schists come in, and no more gneiss is seen till above Nandan; on the road to Joru, a band of gneiss or gneissose granite was crossed.

The gneiss seen in the Chenab valley was the true bedded gneiss such as is seen on the Babeh pass section and not a gneissose granite. The junction with the schist series could not unfortunately be observed on a traverse, and I am at present uncertain whether there is a gradual transition or unconformable break.

In the valley crossed by the road a few miles before reaching Badrawár felspathic rock again appears underlying the schists. What was seen was all very decomposed, so its true nature was not determinable and I am not certain whether it is a true gneiss or a metamorphosed arkose rock. To a slight degree it resembled the latter, but it is altogether more probable that it is either a true gneiss, or gneissose granite. The dip of the beds is to north-east at 30° to 40° on the average and the whole termination of the spur is gneiss.

The rocks composing the ridge crossed between this valley and the town of Badrawár are schistose slates, so much less metamorphosed than those to the north and exhibiting so sudden a change that it is probable they are brought in by a fault.

At Badrawár innumerable blocks of gneissose granite may be seen, which have come from the west down the streams draining from the Kund Kaplas, but the rocks *in situ* as far as Tenála were grey slates dipping north-eastwards. From Tenála on, my route has already been described by Colonel McMahon, and on a mere traverse I saw nothing of importance to add to his description.

Note on Blown-Sand Rock Sculpture; *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With one plate.)

There is a very general impression that the striated surfaces produced by blown-sand are similar to those produced by glacial action, and when pebbles

shewing what are believed to be glacial striæ were lately sent to Europe from the boulder-bearing beds at the base of the Speckled Sandstone series of the Salt Range, suggestions were hazarded that they might have been produced by the action of blown-sand, yet so far as my experience goes, and as far as I can compare it with the published accounts of the observations of others, there is no real similarity between the effects of two such different agencies.

In the Desert region between the Aravalis and the Indus there are many opportunities of studying the effect of blown-sand, and during the season of 1886-87 I was able to collect some specimens exhibiting its peculiarities. One of these is depicted in the accompanying plate.

The principal characteristic of a surface smoothed by blown-sand lies in numerous broad and shallow grooves, deepest at the end from which the wind blows and growing shallower as they advance, giving the surface an appearance of having been roughly dressed with a carpenter's gouge. The scale of these grooves varies largely; on the surface of the limestone plateau near Jessalmer they are two or three yards long and four to six inches broad, on quartzite boulders or the hard glassy sandstone which occasionally occurs they are no larger than those depicted in the plate. This form of surface does not result from want of homogeneity of the rock for it is exhibited alike by the homogeneous limestones of Jessalmer and by pure quartz pebbles,—in the latter case, however, very obscurely, as might be expected, considering that the rounded sand grains can have very little erosive action on quartz. In the specimen of grit and conglomerate drawn, there are of course variations of texture, but these do not appear to have influenced the sculpturing which traverses the matrix and the enclosed pebbles indiscriminately.

Apart from this peculiar sculpturing the nature of the polish imparted to all hard rocks and pebbles exposed to the drifting sand is peculiar; all are highly polished, and where, owing to the disintegration of a conglomerate, the ground is covered with pebbles, they glisten in the sun in a manner that makes it painful to travel over them. This polish is however very different to that of a lapidary and rather resembles what would be produced by oil or grease. The polish sometimes seen on a glaciated pebble, on the other hand, resembles that produced by a lapidary; for all the irregularities of the surface are rubbed down, while the sand-blast polishes all the little irregularities of the surface, alike on eminence and hollow.

Re-discovery of Nummulites *in* Zánskár, *by* TOM. D. LA TOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.* (With one plate.)

In Vol. XXII of the Memoirs, Geological Survey of India, at page 115, under the heading 'Reputed Tertiaries in Zánskár,' mention is made of certain nummulites, said to have been obtained by Dr. T. Thomson in 1852 from the Singhe lá, on

the road between Khalsi on the Indus and Padam in Zánskár, which nummulites were described by MM. D'Archiac and Haime in 1853 as N. raymondi (*ibid.* p. 11). The writer of the Memoir goes on to say: "The majority of the rocks on the Singhe lá consist of dolomites, limestones, and slates of mesozoic age; and as tertiary rocks have not been detected among them, the reputed origin of these nummulites must be regarded as open to a very strong element of doubt;" and suggests that they may have been obtained from a pass with a similar name, the Shingo lá, between Leh and Skiu, on which nummulitic rocks are plentiful (*ibid.*, p. 107) though, "as Dr. Thomson did not apparently traverse this route, it seems doubtful if this solution of the difficulty can be admitted."

Having recently had occasion to cross the Singhe lá (Singala of Quarter Sheet, 45 S.W. of the Atlas of India, in approximate Lat. 33° 58′ N., Long. 76° 58′ E.), I made a search for these nummulites, and was fortunate enough to find them, thus confirming the accuracy of Dr. Thomson's statement. Moreover, I was able (the pass and surrounding hills being almost free from snow) to trace the fragments of rock in which the fossils occur on the pass to their source, and to make some observations on the relations of the nummuliferous rocks to the underlying mesozoics.

I first came upon the nummulites at Linshot, a village at an altitude of 12,850 feet, lying on the southern slopes of the range crossed by the Singhe lá, and about 5½ miles to the west of the pass. Here they occur in numerous large boulders of limestone, embedded in the drift with which the valley is partially filled. Some of these boulders are of very large size, one measuring 40 feet by 20 feet in diameter, and are generally crowded with nummulites. They have evidently been carried down from above the precipitous scarp, north of the village, probably by a glacier, though at the present day there are none on the southern side of this range. The rock containing the nummulites is a very dark grey limestone, weathering to a sooty black colour, and giving a strong fetid odour when struck or broken; it is traversed by numerous thin veins of calcite.

Between Linshot and the Singhe lá fragments of the same limestone, filled with nummulites, are very numerous in the talus along the foot of the scarp to the north, especially in the valley in which the village of Chunpa-do-Goma is situated, where the talus is almost entirely composed of them. Blocks of grey quartzite from the underlying mesozoics, forming the base of the scarp, are also very common. Fragments of the nummulitic limestones continue to be found across the Singhe lá in the talus from the cliffs to the west of the pass, but none in that on the east; and to the north as far as the large side stream, joining the main valley about halfway between the pass and Phothoksar. This stream drains the northern side of the range between the Singhe lá and Linshot. Further north than this, as far as the Spangthang valley above Honupatta, west of the Sirsa lá (Sirsirla), beyond which I did not go, I could find no trace of the nummulites.

The rocks from which these fragments have been derived thus appear to be confined to the higher portion of the range immediately west of the Singhe lá. Owing to want of time, I was able to ascend the range at only one point, *viz.*, to the peak marked Z⁴ on the map; here, at an altitude of about 18,500 feet[1] at the base of

[1] Water boiled at 179·9° F. and on the pass (16,601 feet according to the map) at 183·3° F, a difference of 3·4°, which corresponds to about 1,900 feet difference in altitude.

two precipitously-scarped masses, rising to 500 or 600 feet higher, and forming the summit of the peak, I found nummulites *in situ*, and numerous fragments crowded with them fallen from the cliffs above. These two masses are built up of layers, from a few inches to over a foot in thickness, of the same black fetid limestone that is found in fragments in the talus below containing nummulites; the beds dip inwards from the north-east and south-west respectively at an angle of about 20°, forming a shallow synclinal with its axis directed downwards towards the south-east, so that the same limestones occur at a much lower level than in the peak, at the top of the scarp running west from the pass towards Linshot.

It was difficult to make out the relations of the nummulitic limestones with the underlying rocks, owing to the manner in which the hill-sides below the peak are smothered in talus, outcrops of the rocks beneath only showing through in detached patches; and this difficulty was increased by the sharp folding which the whole of the rocks have undergone. The limestones, however, appear to rest conformably on thick beds of grey quartzite, which in turn are underlaid by shales forming the pass itself. To the east succeed mesozoic limestones and slates, much folded and inverted, so that at the pass they appear to be resting on the shales. These relations I have attempted to shew in the accompanying section, but am not inclined to guarantee its accuracy in every detail.

The apparent conformity between the nummulitic limestone and the quartzite may have been superinduced by folding subsequent to the deposition of the tertiaries, for in the Indus valley the nummuliferous beds occur in the higher zones of the series, and there are indications of an overlap on the southern border of that area (Mem. G. S. of I., Vol. XXII, pp. 107 and 110).

It is thus proved beyond doubt that in middle eocene times the southern shore line of the tertiary sea (occupying what is now the Indus valley) did run out far to the south, as Mr. Lydekker supposes may have been the case (*ibid.*, p. 120), and included the Singhe lá. How much further to the south this sea extended there is no evidence to shew, as no nummulites have yet been found on any of the passes between the Singhe lá and the great range south of Zánskár; but the absence of conglomerates, such as are found in the Indus valley below the nummulitic beds, beneath the limestones of peak Z^1, would seem to shew that the shore-line was at a considerable distance. That it was not connected in this direction with the sea occupying the basin of the outer hills, seems fairly certain, for in the lower Chenab valley, where two large inliers of Zánskár rocks occur, Murree sandstones are found immediately in contact with the mesozoics of the upper and nearer inlier, while in the lower and more distant one nummulitic limestones intervene, thus indicating a shore-line to the north in that area in middle eocene times (*ibid.*, p. 92).

This confirmation of Dr. Thomson's discovery affords further evidence of the enormous earth movements that have taken place in the north-west Himalayan area since early tertiary times, whereby marine strata have been elevated more than 18,500 feet above the present sea-level. As far as I am aware, this is the greatest altitude at which marine fossils have hitherto been obtained *in situ*.

Notes on some Mica-traps from Barakar and Raniganj, *by* PRAMATHA NATH BOSE, B.Sc. (Lond.), F.G.S., *Deputy Superintendent, Geological Survey of India.*

The specimens described below were collected during a short excursion with the Director to Barakar and Raniganj towards the end of last August. The time at our disposal was too short and the weather too unpropitious for a systematic study of these highly interesting rocks; and my only reasons for publishing the following rough notes, based on three specimens, all more or less decomposed, are the scant attention which their petrography has received hitherto, and the possibility of its not receiving further attention at least in the immediate future. Dr. Blanford described them twenty-eight years ago in the following terms[1]:—

"The trap forming the various dykes differs greatly in mineral character. It is generally more or less decomposed, and frequently contains a whitish micaceous mineral, somewhat resembling margarodite in little rounded masses. In many cases it contains black mica."

And this is, I believe, the only description we have of the rocks.

The mode of occurrence of the mica traps, and their probable age, have been discussed by Dr. Blanford.[2] They occur as dykes and intrusive sheets, altering the rocks in contact, and often ramifying through the coal. The action of contact metamorphism on the coal has almost invariably resulted in the production of a columnar structure in it. The columns are usually hexagonal, and invariably perpendicular to the direction of the dykes and sheets. Sometimes they radiate from a central core composed of the intrusive rock. Some beautiful examples of the radiating arrangement were seen at the Laikdih quarries near Barakar. The contact coal has been hardened, and is left in the pits and quarries, being considered worthless as fuel.

The following assays of two specimens of contact, columnar coal, made by Mr. Hira Lal in the Survey laboratory, will shew their composition.

An analysis of a good sample of the normal Barakar coal is also given for the sake of comparison.

	Columnar coal.		Normal coal.
	No. 1.	No. 2.	
Moisture	3·38	2·98	2·48
Volatile Matter (exclusive of moisture)	9·02	7·62	28·72
Fixed Carbon	68·60	78·00	60·20
Ash	19·00	11·40	8·60
	100·00	100·00	100·00

[1] Mem., G. S. I., Vol. III, p. 142.

[2] Op. cit., pp. 141, &c.

The contact coal burns very slowly. It is not, as has been observed above, raised at present.

The dykes and intrusive sheets are, as observed by Dr. Blanford, "almost confined to the Lower Damadas. A few instances, however, occur in the Raniganj Series." The specimens from the Raniganj mine described below are from dykes which have intruded through the latter.

With regard to the geological age, Dr. Blanford saw "good reason for supposing that these intrusions may have been contemporaneous with the great volcanic outbursts, of which evidence exists in the Rajmahal hills;" and the balance of probabilities appeared to him to be in favour of their being of Rajmahal (Upper Gondwana) age.[1]

The intrusions from which the following specimens were obtained are all very small, not exceeding six feet across.

As far as I am aware, Mica-traps have not been described from any other part of India. They are found intrusive in the older Palæozoic rocks in England (Westmoreland and Yorkshire), in the Southern Uplands of Scotland, and in several localities in Ireland. They are also met with in the Channel Islands, Saxony, the Vosges Mountains, Baden, North-Western and West Central France, and in the Pyrenees.[2]

No. $\frac{8}{384}$ (Laikdih quarry, near Barakar), sp. gr. 2·77. Grayish rock with abundant flakes of biotite visible macroscopically; effervesces with hydrochloric acid. Fracture, uneven.

Under the microscope, the ground-mass is found to be microcrystalline. There are abundant rod-like, translucent microlites, some of which probably belong to plagioclase. There is also some apatite. Minute specks of viridite abound; and some cloudy dark-brown, opaque specks and patches (decomposed mica and ferrite), and a little magnetite also occur. There are, besides, irregular, nebulous, finely grenular, greyish patches which shew strong double refraction, observable with the analyser alone. Some of these patches occur in association with secondary quartz presently to be mentioned. From their behaviour, they appear to me to consist of calcareous matter—the result, in all likelihood, of decomposition.

There are, in the ground-mass, polygonal or rounded spaces, in which shadowy outlines are discernible in transmitted light; the finely granular substance just mentioned bays into some: and magnetite is sometimes found enclosed. With polarised light some of these spaces are clearly seen to be filled with quartz (secondary), exhibiting a mosaic play of colours, and others with a zeolite shewing beautiful radiating structure. The two (quartz and zeolite) are in some cases associated together.

Some of the biotite crystals are large, which are visible macroscopically, but the majority are minute, visible only under the microscope. They exhibit strong dichroism. The larger crystals have frayed edges.

There is no well-developed felspar, nor is any pyroxene or amphibole visible.

[1] Op. cit., pp. 144-145. Colonel McMahon, from a lithological study of the Deccan and the Rajmahal traps, suggests the possibility of their being contemporaneous (Rec., G. S. I., Vol. XX, p. 110).

[2] Bonney, Q. J. G. S., Vol. XXXV, p. 165.

If the felspar microlites mentioned above really belong to plagioclase, the rock may be called *kersanton.* There is present 48·48 per cent. of silica according to an analysis made by Mr. T. R. Blyth in the Survey laboratory.

No. $\frac{8}{283}$ (Raniganj Mine). Sp. gr. 2·45. Greyish-green compact rock; effervesces, but very slightly, with hydrochloric acid. No crystals are visible macroscopically.

Under the microscope the ground-mass is seen to be microcrystalline. Minute crystals of biotite are very plentiful. It is the predominant mineral, as in the last specimen. There are some lath-shaped, badly-developed crystals of plagioclase. They occur as single individuals, and exhibit no twinning. A few crystals of hornblende occur, which shew characteristic cleavage, and marked pleochroism with polarised light. In these a granular or fibrous greenish decomposition-product sometimes appears. It is probably identical with a similar mineral which is rather abundant and which has, as a rule, a rather well-defined contour. If so, there can be no doubt that this mineral is the result of decomposition of the hornblende. With a single Nicol, the mineral in question shews very feeble dichroism, or none at all; in all probability it is chlorite. Greyish cloudy patches similar to those which have been described as occurring in the last specimen occur, but are not so abundant. Sometimes they shade off into the greenish decomposition-product just mentioned There is a little magnetite. The percentage of silica present in the rock, determined by Mr. Blyth in the Survey laboratory, is 51·68.

The rock may be called *kersantite,* if the presence of hornblende be a sufficient ch racter to distinguish it from the last specimen.

No. $\frac{8}{282}$ (Raniganj Mine). A greyish-brown, mottled, vesicular rock. No crystals are visible with the unassisted eye.

Under the microscope, the ground-mass is seen to be microcrystalline. It is crowded with minute, badly-developed crystals of biotite. There are some long lath-shaped crystals of plagioclase, all of which appear to occur as single individuals, as in the last specimen. Greenish specks and patches abound, as in the last specimen, but no hornblende is observable. There is a little magnetite and some secondary quartz. The percentage of silica present in the rock, determined by Mr. Blyth in the Survey laboratory, is 57·88.

ADDITIONS TO THE MUSEUM.

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Concretions from beach abreast Saugor light-house.

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Three specimens of the meteoric irons of Youngdegin, Nejed, and Greenbrier County.

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PRESENTED BY B. V. ROYDU, MAHARAJA, NAGPUR.

Limestone from Birds' Nest or Elephant Island caves, South-East of Domel Island, Mergui Archipelago. PRESENTED BY COMMANDER A. CARPENTER, R.N., H. M. I. M. S., "INVESTIGATOR." PORT BLAIR.

Graphitic shale (containing 19·33°/₀ carbon), and carbonate of lime, from near Rampur, on the Murree-Kashmir Road.
PRESENTED BY E. S. FARRANT, C.E., EXECUTIVE ENGINEER TO THE RESIDENT IN KASHMIR.

Fossils (proboscidian) found on a hill above the village of Khyrabad in the Salt Range, a few miles from Mari, Kalabagh, Punjab.
PRESENTED BY P. P. DEASE, EXECUTIVE ENGINEER, MARI, KALABAGH DISTRICT, EDWARDESABAD.

Four specimens of crystalline rocks, from different localities, collected during a trip from Mussoorie to Gangutri. PRESENTED BY DR. H. WARTH.

Cobaltiferous *matt*, from Kachipatar, Nepal.
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PRESENTED BY MAJOR W. LOCH, SETTLEMENT OFFICER, MARWAR.

Twenty specimens of rock salt: from the Mayo Mines, Salt Range.
PRESENTED BY MRS. W. KING.

A specimen of wolframite: (said to be from Hazaribagh District).
PRESENTED BY J. C. M. FORBES, CALCUTTA.

Three specimens of laterite, and 1 of slate: from the Kharakpur Hills, Durbhunga Raj.
PRESENTED BY T. M. FRANCIS, DURBHANGA.

Seventeen fossils (mammalian, shells, &c.): found on a hill above the village of Khyrabad in the Salt Range; and a specimen of fossil wood found embedded in the sandstone rock near the village of Shivaki in the Kohat District.
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Specimen of coke made from Karharbali coal in the Welsh coke oven.
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Peat found at the bottom of a Railway well at Dattapookar.
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Samples of pig iron, Nos. 1 to 5, from the Government Iron Works at Barakar.
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October 8th, 1888.

Government of India Central Printing Office.—No. 10 D. G. Survey.—4-12-88.—630.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXII.

Published by order of His Excellency the Governor General of India in Council.

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY,
(AND BY ALL BOOKSELLERS).
LONDON: TRÜBNER & CO.

MDCCCLXXXIX.

CALCUTTA:
PRINTED BY THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA,
1889.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1889. **[February.**

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1888.

PENINSULAR INDIA.

Messrs. Foote, Hughes, and Lake.

Madras diamond fields.

MADRAS PRESIDENCY.—*Crystalline rocks,—Archæan.*—Accompanied by the Superintendent for Madras during part of one of my tours, I have again visited some of the diamond-producing areas in the Bellary and Kurnool Districts, more particularly with a view to the elucidation of the occurrence of these gems at Wajra Karur, where no outlier or remnant of the recognized diamond-bearing beds (*Banaganpillis* of the Kurnool series) exists. The original source, or parent rock for diamonds, has always been the object of our search; for it gradually became evident—to myself last of all among my colleagues—that the gems known to occur in the peculiar gravelly shales near the base of the Banaganpilli sandstones may really be only pebbles just as much as the waterworn detritus with which they are associated, and now it would almost seem as if we were on the eve of learning of such an original source occurring in volcanic intrusions in the crystalline rocks or gneisses of the Bellary District. I say, of learning, because if it eventually turn out that the diamonds of Wajra Karur do occur in the rock supposed to contain them at that place, then the discovery will be due to non-official or private exploitation of the country. The fact remains that diamonds are found in the surface soils and gravels of Wajra Karur (and at other places also in the Bellary District), on the summit of a low water-shed where at present there is no visible parent rock at a higher level whence they could have been derived. On the other hand, it is said, and has been reported in other papers as well as in the Records of the Survey, that a "neck" of igneous rock occurs among the gneisses there which bears some resemblance to the Kimberlite (*var.* peridotite), or "blue" (miner's term, not a blue clay) of the Cape diamond fields; and it is also said, but not authoritatively, that some of the diamonds of Wajra Karur have been found in it. A paper by Mr. Foote, bear-

ing on this so far curious and unique question, appears in the present number of the Records, in which it will be seen that he doubts whether diamonds can exist in this "neck" rock, and that he prefers rather to conclude that the diamonds of this place occur only as part and parcel of the superficial debris, having been derived from a long-disappeared upper portion of the same "neck" rock which had passed through some carbonaceous deposit which in past ages has also been worn off the face of the country. I prefer myself, as yet, to consider that these diamonds are from the debris of outliers of Banaganpilli sandstone which once existed near or at Wajra Karur; small outliers of such rocks having only lately been mapped by Mr. Foote much further south-westward of Kurnool than we had anticipated. In the meantime, we have not been able to detect any diamonds in the specimens of "neck" rock which have come under our treatment.

Madras gold-bearing rocks.

Transition; the Dharwar Series.—Mr. Foote has been engaged all the year on this economically important series of rocks; and his concluding observations on them, so far as they are fitted for preliminary publication in these Records, are given in the present number, the first instalment of them having appeared in the May issue. A map showing the distribution of the different bands of the series, and the known localities of gold occurrence, was also given in that number; so that the whole report should prove eminently useful in the further and, I may almost say, assured progress of the gold industry in the Madras Presidency. The area over which these bands of transition rocks occur in Southern India is enormous, stretching in a more or less north-north-west, south-south-east direction from about the 17th to beyond the 13th parallel of north latitude; and distributed over a breadth of 192 miles: while the number of spots in this huge tract which have been mined in past times and by a so far unknown people is very remarkable. The story of the struggles and ultimate success of the Kolar gold mines (which occur in the easternmost of these bands of Dharwar rocks) up to the present is well known: but if we may place any reliance on the geological relations of the series, and on the ancient working of that auriferous tract, the conclusion that other gold fields of equal if not superior richness are still lying fallow seems almost inevitable; indeed, the mere distinction of this series of rocks by the Survey has led to the recognition within the last year by Mr. Hughes of one of those in the Raichore Doab, where the extent of old mine workings, and the evidences of the means adopted for crushing the ore are marvellous.

I took the opportunity while still with Mr. Foote of re-visiting the Kolar tract as also this newly-found area in the Raichore Doab, when I was struck with the wonderful similarity in many features of the two regions; and at the same time was glad and indeed proud to recognize the *bonâ fide* scientific value and accuracy of the report of my colleague Mr. Hughes in his so much questioned though officially sanctioned connection with the Hyderabad Deccan Company.

NIZAM'S DOMINIONS. Coal-fields.

Lower Gondwana.—The economic value of the extension of this formation down the valley of the Godavari river and on the drainage area between that river and the Kistna, has at last been brought into prominent notice by the successful exploitation of the Singareni coal-field by Mr. Hughes. The fact of the occurrence of

this outlying patch of coal-measures was made known so far back as 1872, and it is some satisfaction to the Survey, after so many years of waiting for its final development, that this should have been reserved for our colleague. At the close of Mr. Hughes' deputation with the Hyderabad Deccan Company, I revisited the tract under the further light which has been thrown upon it by shaft and incline workings, as well as to test—if there were any need of that—the value of the reports furnished by Mr. Hughes to his employers. This inspection has more than justified my original appreciation of the field, as also my later view of its possible capabilities in 1883 when I estimated that seventeen million tons of coal may be reasonably relied on. The borings which were put down by the Nizam's Government turn out, I regret to find, to be unreliable; nevertheless the new survey, borings, and workings show that the coal, though cut off at times by faults, is there in all its natural extension and quality. I do not think that Mr. Hughes over-estimated the conditions of the field when he reported as follows in 1887:—

"(*a*) Its area is greater than that of the Umaria estate and the Karharbari field.

"(*b*) The character of such of its coal as came within the range of inspection and practical trial has been declared by practical authorities. It is a good steam coal, has little or no clinker, contains only the average amount of ash, withstands weathering, and, from its texture, will bear handling.

"(*c*) The entire series of coal measures is within easy reach of the surface, and there are the unknown possibilities of superior fuel occurring in the seams which have not been opened out.

"(*d*) The field is beyond the range of detrimental competition, and it can claim the advantage of an assured consumption of 180,000 tons of coal per annum.

"(*e*) The covering, cost of cutting, winding, and loading coal into wagons at the pit's mouth ought not to exceed R2 a ton, when full raisings are established."

Since then, or at the end of June 1888, the output of the colliery workings is recorded at 70 tons of round and 20 of small coal, or a total of 90 tons a day.

As to the powers of the coal, the Locomotive Superintendent of the Nizam's Railway reports in June 1888:—

"The condition of the trials as regards train loads and locomotive engine power were ordinary, and the results obtained may be taken as reliable data upon which to form an opinion of the quality of the Singareni coal supplied as a locomotive engine fuel. The coal was of average merit and not selected.

"The following were the averages:—

	lb.
Coal per train mile	33·47
Water evaporated per pound of coal	6·36

Tertiaries of the West Coast.—Mr. Lake, having had his initiatory season of Indian geological work in company with Mr. Foote, was posted at the commencement of the present field season to the working out of the geology of the West Coast in the long tract of country between Cochin and Karwar. This is one of the few blank areas in the map of the

Traces of oil shales.

general geology of India which has remained unexplored; and already, though somewhat delayed by sickness, it is satisfactory to report that Mr. Lake's observational powers are of immediate value in so far as he has noted a possible relation between the existence of an oil shale among the strata underlying Calicut, and the movement of the mud bank at that place. This observation, though it does not as yet give any promise industrially, seems to throw further light on the smooth water tracts of Cochin and Alleppy to which I drew attention in 1884, in connection with the fact that the mud dredged from the banks underlying them had yielded a trace of oil.

A find of marine shells in the laterite of Malabar, and the recognition of two distinct levels of laterite, are important additions to our still very imperfect knowledge of this protean formation.

Mr. Bose. Sub-Assistant Kishen Singh.

Central Provinces.—*Transition; Bijawars.*—The question of the exploitation of the manganiferous deposits at Gosalpur and other places in the Jubbulpore District having again been opened by the Central Provinces Government, Mr. Bose was deputed to make a thorough re-examination of the area. This was a close and intricate business, involving the making of several shallow pits and cross-cut trenches, and it occupied the whole of the working season; the result being two reports, the first of which, having to do with the practical bearings of the question, appeared in the August part of the Records, while the second (not yet published) dealt with the theoretical aspect of these unusual occurrences among the Bijawar rocks. Mr. Bose estimates the total quantity of *pyrolusite* (manganese ore) at Gosalpur at about 50,000 tons, while from the Sihora tract, and other neighbouring localities, about 26,000 tons may be reckoned on. The manganiferous hæmatites may be considered as practically inexhaustible.

Gosalpur manganese ores.

The whole enquiry, however, remains very much as it was originally discussed by Messrs. Medlicott and Mallet; though there is no doubt that Mr. Bose's survey has added very materially to our knowledge of the region in the matter of details, while he has kept the problem regarding the origin of the pyrolusite well before him. The evidence, so far indeed, shows that the distribution of this ore may be very largely, if not entirely, attributable to sub-aerial influences which seem to have prevailed with greatest intensity during an early stage of the Recent or perhaps Post-pliocene period, one form of their action having been *lateritization,* if we may so designate that chemical change or alteration resulting on weathering, concomitant with infiltration of iron peroxide (and rarely manganese oxide), which has certainly in some cases at least taken place on the transformation of certain rocks into laterite. A point of considerable interest in this connection is that it was in the Gosalpur neighbourhood that Mr. Mallet saw cause for suggesting the leaching out of the manganese from the adjacent manganese iron beds of the transition series, as accounting for the occurrence of what may be called a *manganese laterite* as distinct from the ordinary iron or ferruginous laterite: a distinction of some importance, leading as it does to the supposition that the few indications hitherto observed (not the least of them being that noted in the Bidar laterite by Captain Newbold so far back as 1844) of manganese ore among the laterites of the Madras Presidency may point to a wider occurrence of these ores than has hitherto been presumed.

Manganese laterite.

Since the commencement of the present field season, Mr. Bose has again resumed work in Balaghat among the Transition and Vindhyan rocks; which in that region, and for the present, are classed under the local names of the Chilpi series and the Chattisgarh Vindhyans, though the former certainly bears in some respects a close resemblance to the Bijawar series in the Narbada Valley, and yet in other respects a much closer likeness to the Dharwar series of the Madras Presidency. For the present, however, a special economic relation between them and the Bijawars of the Narbada Valley lies in the existence of the Balaghat manganese, for the examination of which Mr. Bose's recent experience at Gosalpur must have well fitted him.

Balaghat Transitions and Vindhyans.

Deccan Trap Series.—Babu Kishen Singh has carried on the boundary of the Deccan Trap in the Chindwara District as far westwards as the Chindwara-Nagpore high road, where he has also followed the Lameta or Infra-trappean deposits as well as the much less continuously distributed Inter-trappean beds which are occasionally fossiliferous. His progress report is fairly interesting and full of details of the ground and of the specimens he has sent up to head-quarters, all of which will prove of increased value when this great formation of the Deccan comes to be more closely studied. Kishen Singh has now been placed with Mr. Bose for further training among the more intricate and difficult, as well as somewhat economically interesting rocks of Balaghat.

CENTRAL INDIA AND RAJPUTANA.—*Transition Series.*—My hopes regarding Mr. Hacket's being able to extend his observations sufficiently to the westward of Jodhpore to touch on the Gondwanas have not been fulfilled. His season's work lay to the westward of Mt. Abu, and the Aravallis, and it is laid down on sheets 74 and 75, and portion of sheets 93, 94, 95, 96, and 97 of the Topographical Survey maps: but partly from the increasingly complicated association of the different series of the very altered rocks in that region, and the disconnected way in which the ridges and outcrops of these show among the intervening sand wastes; and mainly, I fear, from broken health and failing energies, little further way has been made towards a solution of the geology of that region. Mr. Hacket's service was completed on return to head-quarters from the field, and he retired in July last.

Messrs. C. A. Hacket and R. D. Oldham.

A very peculiar and almost unique (for India) decomposition-form of certain quartzites belonging to the transition series has been long known under the name of "flexible sandstone," as occurring at Kaliana in the Jheend State; and enquiries having frequently come from Europe, and specially from America for specimens, opportunity was taken after he had finished the search for supposed petroleum in Ulwar, of Mr. Oldham being in the neighbourhood for obtaining specimens and ascertaining as much as possible concerning the stone and its occurrence in this hitherto unvisited locality. A note on the nature and mode of its occurrence, and the cause of its flexibility, is given in the present Records; and duplicate fragments of the rock are available for museums.

Flexible sandstone.

BENGAL PRESIDENCY.—*Crystalline Series.*—Renewed search for materials required for the increased development of the iron industry at the Barakar Works was taken up at the earnest solicitation of Ritter von Schwartz, and later on, to meet the demand raised

Mr. E. J. Jones and Sub-Asst. Hira Lal.

by Mr. Manneberg who came out to this country under an introduction from, or at the instance of, the Secretary of State for India, to the Government of Bengal in connection with these Iron Works. Mr. Jones was deputed for this enquiry, when he made a more rigorous and detailed examination of the dolomite of Dhelwa in Hazaribagh, and the limestones at Raniganj, Simaltala, and Pachete hill proving that stone of the pure composition demanded was available in sufficient quantity. He also pointed out sites for bore-holes, which have led to the knowledge of stores of coal which should raise the value of the estate proportionally.

Limestone for Bengal Iron Works.

Lower Gondwana.—Babu Hira Lal is still engaged in mapping the extensive coal tracts of the western portion of Chota Nagpur: his progress report for the last season being a description of portions of the Rampur, Sirgujah, and Lakhanpur coal-fields and parts of the adjacent area. All the coal outcrops have been examined and recorded, while assays have been made of such seams as were thought worth trying, some of them giving very fair results. His progress report, with accompanying portions of four sheets of the Chota Nagpur topographical survey, on a scale of one mile to the inch, are very creditable results of the season's work.

Chota Nagpur coal-fields.

An attempt is at last about to be made by the Bengal Government to ascertain the capabilities of one of the coal-fields of the Rajmahal hills. The only effort hitherto in this way was, I believe, made on the eastern edge of these hills near the town of Rajmahal itself, which, had it been successful, would have opened up a most convenient source of supply for the deltaic system of railways. The boring was intended to have been run down 500 feet, but the attempt fell through before this depth had been attained. Attention is now being directed to the western side of the hills on what has been called the Hura coal-field, where outcrops of coal had been quarried long ago and a quantity of coal extracted, until the workings fell in and so obscured all further enquiry into the quantity or quality of the fuel. Boring is the only course to be followed out now for ascertaining anything further: and advice was given on this point. After a delay of some six months owing to the difficulty of getting any one to take up a contract for the boring, a further advance has been made: and, for the satisfaction of all parties, Mr. Jones was sent out in company with the District Engineer to select sites. He reports that such coal as could be seen or picked up is not of a very promising quality; but this cannot be taken as a fair indication of what the borings may show, and the field should not now be left with any doubt as to its value.

Rajmahal coal.

Delay in Boring exploration.

The present case is only a further instance of the unsystematic and indeed mixed way in which mining investigations are occasionally carried out by Government in this country, where such work has always been done directly by the Department of Public Works, and indirectly through advice from this Department. Much of the evil attending such a mode of procedure may be attributed to the notion that it is just as easy here in India, where mining work is as yet only very local, to obtain skilled and experienced miners as it is in England: whereas the few men so trained, and on whom any reliance can be placed, are already fixed at the work which

How to meet the difficulty of carrying out borings.

suits them and requires them; the residuum of partially trained hands, or men of all trades with no special aptitude for any, being often worse than useless. There is, above all, the ever-recurring difficulty of finding boring plant, notwithstanding the fact that sets of such plant have been purchased over and over again, owing to loss or that they are stored at too great a distance from the new region of investigation.

Under such difficulties or disadvantages, I now repeat what I have often urged previously, that—in the present stage of mining in India—the Geological Survey Department is, or at least ought to be, best qualified for carrying out such preliminary exploitation. With sets of boring and certain mining plant stored at a convenient centre, and a mining manager with a small staff of subordinates—selected in some cases from men trained in an Engineering School like Sibpore College, I feel confident that mining questions would be settled more quickly,—and therefore at least more economically,—than has hitherto been the case. Indirectly also, by this means, a class of trained and reliable men would be gradually formed in the country from people of the country, ready to fill the many posts now occupied by highly paid men imported from England or the Continent.

EXTRA PENINSULAR INDIA.

Baluchistan and the Punjab.—*Tertiary.*—So many varied reports, followed by enquiries, having arisen regarding the quality and extent of the coal outcrops and oil resources on the north-western frontier, I felt it incumbent on me to see what the actual condition of these developments are. At Khost, on the Sind-Pishin Railway, endeavours were being made by Mr. G. B. Reynolds, of the Public Works Department, to form a plan for working the thin seams of tertiary coal which, owing to the opening up of the railway, have lately assumed a very important aspect. The coal of this region, though not that of Khost itself, had been already briefly visited and reported on by Mr. W. T. Blanford in 1882, when, though the coal is good, the view taken of its extent and facility of being worked was not favourable. The Khost coal occurs, as far as I saw, in two thin seams cropping out at the foot and up the slope of the hills on the south-west side of the valley, a mile or so behind the railway station, dipping into the hill at an angle of 30 to 45 degrees. The outcrops have been grubbed at in all sorts of ways by digging at the surface as long as the ground would hold, or by driving galleries along the seam at a short distance inside the outcrop; and, so far, baskets of very good fuel are landed by coolies at the station at a very low rate, sufficiently so at least to satisfy the N. W. Railway administration. The more prominent seam varies from 2 to 3 feet in thickness, several inches of it being mere shale; so that there may be from 18 inches to 2 feet of good coal at times: it is badly crushed and squeezed, partly through being an outcrop-seam on the steep slope of the hillside, and it is very sulphurous from iron pyrites.

Khost coal.

Of course, the happy condition of the coal being landed at present so cheaply on the railway platform must soon come to an end; so the problem before Mr. Reynolds was how to work a seam so disadvantageously placed. He proposed to run

an incline adit down on the dip of the coal as far as this could be conveniently carried, from the bottom of which horizontal drifts should be run with the seam on either side; the seam to be worked out upwards towards the outcrop. Haulage of coal to be up the adit to mouth and thence by incline down to railway. I have not heard that any progress has been made with this scheme: but in face of the very fitful continuity of the coal, and the extremely unstable character of the beds above and below, necessitating a costly form of holding up the workings, it seemed to me—although the only apparently feasible way of getting the coal— an essentially questionable adventure as far as profitable working went. Under these circumstances, and knowing as we do by Mr. Blanford's report and by what I myself saw in the neighbourhood of Sharigh, that there is horizontality, or nearly so, of the same series of beds with perhaps the same seam of coal; I really think that a close survey of the stratigraphy of the valley should be made before any further extensive scheme for working such untowardly disposed beds as those of Khost be tried.

There remains indeed the hope that the disadvantages connected with the exploitation of coal in Baluchistan may be met by the utilization of the petroleum which has been so successfully brought to the surface by Mr. R. A. Townsend at Khatan:

Khatan oil.

but here again there is the difficulty of transport of the oil which militates strongly against the paying employment of this admirable fuel. As it is, the oil is too thick to flow any distance of its own accord, and it will have to be carried or forced over a very difficult country for some forty odd miles before it can be placed on the railway; while the place of the oil works themselves is about as desert a hilly tract, without supplies of any kind or even drinkable water, as can be imagined for the centre of such an industry. The pity of it is that this region should have been selected for Mr. Townsend's exploitation rather than others of much less inconvenient approach to the railway, where oil-shows were known. There can be little doubt that the oil in Baluchistan, within reach of ordinary boring, is of local occurrence, occurring in or among certain bands of the tertiary rocks, dependent too on particular stratigraphical features; so that it would be rash to bore at haphazard in any position among such beds as we know, for instance, underlie the great plain or 'pat' of Sibi and Jacobabad: but it struck me that as oil-shows are known in the neighbourhood of Shoran, where the rocks rise out of the place in an anticlinal undulation, the place also being more accessible, the Baluchistan oil explorations might be very advantageously directed to that side of the country. I now hear that operations have been commenced there.

I also visited the oil-shows in the Rawalpindi District, which certainly look

Rawalpindi oil.

poor enough, though the quality of the oil so far is superior to any yet seen in Baluchistan, or even in Assam. When, however, the poorness of these shows is compared with what I saw of the indications (pointed out to me by Mr. Townsend) of oil on the surface at Khatan, where, too, what may be called 'live oil' shows do not occur at all; I cannot divest myself of the idea that the deep boring proposed for the Rawalpindi region may yet yield a fair supply, though it too will no doubt have to be raised by pumping, the highly folded and shattered condition of the strata scarcely affording any expectation of a closely confined store of oil.

KASHMIR.—Mr. La Touche's deputation with the Kashmir Durbar has just come to a close; and on this duty he has been able to give valuable information not only on the special question before him, *viz.* the investigation of the occurrence and extent of the sapphire rocks in the Zanskar District, but also on the Jummu coal to which his paper on the Sangar Marg and Mehagala coal-fields, in the Records for May last, refers. At the request of the Durbar he also reported on the iron works and ores near the village of Soap, in the Kashmir Valley, with a view to their further development.

Mr. La Touche.

Sapphires.
Coal.
Iron.

A notice of his in the last part of the Records, on the rediscovery of nummulites in Zanskar, confirms a very interesting observation of Dr. T. Thompson made so long ago as 1852, which observation had been questioned by Mr. Lydekker in his Geology of Kashmir and Chamba. This is the more gratifying as Dr. Thompson's find had been utilised by MM. D'Archiac and Haime in their classical work on the Nummulitic Fossils of India.

Nummulitic fossils.

He also on his return through Murree, endeavoured to meet the pressing question of an improvement in the water-supply; coming to the conclusion that, though the local supply might be increased to a small extent, the necessities of the case can only be met by bringing in water from a distance. A report on the question was furnished to the officer commanding the Rawalpindi Division.

Murree water supply.

HIMALAYAS—*Archæan, Palæozoic, and Mesozoic.*—The tract of the Himalayas at present under survey consists of two parts or sections of the outer ranges: (1) the country extending north-westwards from Haldwani to the Ganges near Hardwar, in the hands of Mr. Middlemiss; and (2) the succeeding Dehra and Simla portion as far as the Sutlej, under Mr. Oldham, with whom, for the present, Mr. Datta is associated.

Messrs. R. D. Oldham, C. S. Middlemiss, and P. N. Datta.

Mr. Oldham, seeing that there has been no general review of our knowledge of the Geology of the Himalayas since the publication of the Manual of the Geology of India, and in the face of the progress made since then rendering necessary the amalgamation of the many isolated accounts of different portions of the range, put forward a valuable paper in the Records of August last, on the Sequence and Correlation of the Pre-Tertiary Sedimentary formations of the Simla region of the Lower Himalaya which ought to meet to some extent the world-wide demand for the latest information on the geology and structure of this special mountain region. His later paper in November on the Geology of the North-West Himalayas gives a further Record of observations in Spiti, Ladak, and Kashmir; such as can only be made, when opportunity offers for the carrying of geological traverses over the higher ranges.

Simla region and N. W. Himalaya.

Mr. Middlemiss contributed a further paper (No. III) on the study of the crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun.

Tertiary.—The survey of the Haldwani-Hardwar tract is so far completed as to have enabled Mr. Middlemiss to send in the MSS. and maps for a finished Memoir, which will be issued early

Garhwal and Kumaun.

this year. It deals with the physical geology of the Sub-Himalayan belt of newer tertiaries, the pre-tertiary or Himalayan sub-groups being treated of incidentally.

Mr. Datta has only just commenced his Indian geological career this field season under the guidance of Mr. Oldham; so that a fair judgment can hardly yet be formed on the style of his work or the application to it of the excellent geological and observational attainments attributed to him in the recommendations for his appointment to the Survey. So far, however, Mr. Oldham's report of him seems to show that his chief patron, Professor James Geikie, must have formed a rather exaggerated if not enthusiastic appreciation of his pupil's attainments: or else it may be—and this is quite possible—that a kind of reactionary numbness or slacking off of the faculties of observation and generalization has followed on the strain of European training in a scientific profession as yet new to the Native of India.

ASSAM.—*Tertiary.*—At my suggestion, Mr. R. A. Townsend, Superintendent of Petroleum Works in Baluchistan, was deputed, during the rains, to look up the oil indications in the neighbourhood of the Naga Hills. The Survey had already reported on these and their geological relations, in the Memoirs of Messrs. Medlicott and Mallet: but it naturally seemed of the highest importance that the views of so experienced a specialist should be placed before us. Mr. Townsend divides the region into two portions for convenience of description,—Makum and Jaipur,—with the latter of which he only formed a slight acquaintance. The report on Makum is very encouraging: but promising as the oil may be in so far as quantity is concerned, it is well to call attention to the fact that there is no evidence (as far at least as the records in this office go) proving its capability of yielding a satisfactory proportion of burning oil on distillation. A sample brought by Mr. Townsend, which has been recently examined in the Survey laboratory, yielded (by volume) 92 per cent. of oil, which was collected in ten equal portions. The first, and lightest, tenth had a specific gravity of ·833, and flashed at 139° F. (Abel's test); the specific gravity of the other portions being respectively ·847, ·858, ·867, ·875, ·878, ·870, ·864, ·861, ·882.

Makum oil-field.

This result is quite borne out by an analysis of petroleum from Assam (presumably Upper Assam) made by Prof. Boverton Redwood (Cantor Lectures on Petroleum and its products), who obtained—

	per cent.
Naphtha	None.
Burning oil	None.
Lubricating oil	94·2.

The analysis, again, of a sample from the neighbourhood of Makum (and very probably from a *bore hole* at Makum) gave 94·3 per cent. of oil, of which all but 2 per cent. (the specific gravity of which is not given) had a specific gravity ranging between ·873 and ·936. (Rec. G. S. of I., VII, p. 57.)

Mr. Townsend's sample was obtained at the surface from a natural oil spring; and, as he justly remarks, "the illuminating value of the crude oil can only be ascertained from samples taken from the oil measures below the surface which have not been exposed to atmospheric influences." But, until such petroleum from below has been examined, it will be as well not to assume what is as yet unproven.

Mr. T. W. H. Hughes and Dr. Fritz Noetling.

BURMA.—The demand for further information regarding the resources of Burma necessitated the deputing of Dr. Noetling to that country; though he can be very ill-spared indeed from his proper post as Palæontologist of the Survey, an enormous and long-stored collection of fossils awaiting his examination and description. So far, however, his employment in Burma has had its value; so much so indeed that his services have been utilized to their fullest extent by the Chief Commissioner both in Mandalay and out in the districts during the working season and in the rains. I am hopeful, however, that arrangements may shortly be made which will allow of his returning to his more special work at the Museum in Calcutta.

Oil.
Iron Ore.
Ruby limestone.

Up to this, Dr. Noetling has examined and reported on the oil-fields of Youang-young, Thayetmu, and other places. He has also recognized Silurian rocks in the Shan Hills, with the limestones of which is associated a very important and extensive band of iron ore; and his latest expedition has been to the Ruby limestone tracts of Maddya and Kya-uhyat, at which he has made some satisfactory investigations.

Tin ores of Tenasserim in connection with visit to Perak.

Mr. Hughes, since re-joining the survey, has been also posted to Burma; and so far has completed a special mission to Perak, associated with the Director of the Department of Land Records and Agriculture for Burma, for the examination of the system under which the various tin mines of that State are conducted. He is now in Tenasserim, where he is to arrange, if possible, for the thorough exploitation of the tin ores of that province.

Survey Publications.—The issues have been the usual current volume (XXI) of the Records, containing sixteen papers, five of these being of considerable economic interest; a Bibliography of Indian Geology compiled by Mr. R. D. Oldham, which will meet a very urgent want of geologists; and the concluding part of the Productus Limestone Fossils of the Salt Range by Dr. Waagen, forming Fasciculus 7, "*Cœlenterata—Amorphozoa—Protozoa*," of the Palæontologia Indica, published early in the year.

In connection with the issue of the Records, it is gratifying to note that, as heretofore, volunteer contributions have been sent in by Dr. Carter and Mr. Lydekker on the fossil finds which it is necessary for us to send home from time to time to specialists in palæontology, while our local contributors are represented by Dr. H. Warth and Commander Alfred Carpenter, R.N.

Library.—1,645 volumes, or parts of volumes, were added during the year: 1,067 by presentation or exchange, and 578 by purchase. The library is gradually becoming the resort of students and others, the issue of books on loan being allowed as far as is possible consistent with due regard to its proper consulting or reference use.

Museum and Laboratory.—Mr. Jones carried on these two sections of the Survey until the return of Mr. Mallet in October from sick leave. Numerous assays and reports on coal, oil, limestone, ores of iron, copper, lead, and other minerals have been made for private individuals and mining companies, in addition to the usual examination of rocks and minerals sent in by the officers of the Department. An interesting enquiry has been made on the constitution of the cobaltiferous "matt"

reported as being produced in Nepal: while a systematic series of experiments likely to lead to the utilization of some of the Indian soapstones in the gas industry at home has been made and reported on, in obedience to a requisition from the India Office.

The Museum record of additions by presentation, exchange, or purchase keeps pace with that of previous years.

Mining Records.—In response to a call which was sent out to the different coal companies, arising out of an indication in the public papers of a renewal of the question of mining inspection which I considered need hardly be opened as yet; a very cordial co-operation was evinced by the promise of a fresh series of maps, sections, and other records from:—

Messrs. Apcar & Co.,
Messrs. Bird & Co. for the Alipur Coal Co.,
The Bengal Coal Co.,
The New Birbhum Coal Co.,
The East Indian Railway,
The Ranigunj Coal Association,

the last two Companies and Messrs. Bird & Co. having already sent in their records.

International Geological Congress.—The Survey was represented at the gathering of this assembly of geologists in London in September last by Mr. Medlicott, the late Director, and by Dr. W. T. Blanford, President of the Geological Society. Mr. R. D. Oldham, also, had an opportunity while on privilege leave of exhibiting specimens of interest from India. The acknowledgments of the department are due to the Direction for presentation in advance of copies of Sheet 24 (CIV), and the Scale of Colours of the new International Geological Map of Europe, forwarded by Mr. Blanford.

WILL. KING,
Director, Geological Survey of India.

January 31st, 1889.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1888.

ALBANY.—New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—John Hopkins University.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
" Königlich Preussische Geologische Landesanstalt und Bergakademie.
" Royal Prussian Academy of Science.
BOLOGNA.—Royal Academy of Sciences.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
" Bombay Observatory.
" Marine Survey of India.
" Meteorological Department.
" Natural History Society.
BORDEAUX.—Linnean Society of Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Queensland Branch, Royal Geographical Society of Australasia.
" Queensland Museum.
" Royal Society, Queensland.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Geographical Society of Belgium.
" Royal Malacological Society of Belgium.
" Royal Museum of Natural History, Belgium.
BUCHAREST.—Bureau Géologique, Roumain.
BUDAPEST.—Hungarian Geological Society.
" Hungarian National Museum.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
CAEN.—Linnean Society of Normandy.
CALCUTTA.—Agricultural and Horticultural Society.
" Asiatic Society of Bengal.
" Editor, Indian Engineer.
" Editor, Indian Engineering.
" Indian Association for the Cultivation of Science.
" Meteorological Department, Government of India.
" Survey of India.
CAMBRIDGE.—Philosophical Society.

CAMBRIDGE, MASS.—American Academy of Arts and Sciences.
„ Museum of Comparative Zoology.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DIJON.—Academy of Sciences.
DRESDEN.—Isis Society.
„ Royal Mineralogical Museum.
DUBLIN.—Royal Geological Society of Ireland.
„ Royal Dublin Society.
„ Science and Art Museum.
EDINBURGH.—Royal Scottish Society of Arts.
„ Scottish Geographical Society.
GENEVA.—Société de Physique et d'Histoire Naturelle.
GLASGOW.—Glasgow University.
GÖTTINGEN.—Royal Society.
HALLE.—Kais. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
HARRISBURG.—Second Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Sciences.
LEIDE.—École Polytechnique de Delft.
LEIPZIG.—Geographical Society.
LILLE.—Société Géologique du Nord.
LISBON.—Geological Commission of Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Museum.
„ Geological Society.
„ Iron and Steel Institute.
„ Linnean Society of London.
„ Royal Asiatic Society of Great Britain and Ireland.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
MADRID.—Geographical Society.
„ Royal Academy of Sciences.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-supply, Victoria.
„ Geological Society of Australasia.
„ Public Library, Museums, and National Gallery, Victoria.
„ Royal Society of Victoria.
MILAN.—Society of Natural Science.
MINNEAPOLIS.—Minnesota Academy of Natural Sciences.

MONTREAL.—Geological and Natural History Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAPLES.—Royal Academy of Science.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
„ The Editors of the "American Journal of Science."
NEW YORK.—Academy of Sciences.
OXFORD.—Oxford Museum.
PARIS.—Academy of Sciences.
„ Geographical Society.
„ Geological Society of France.
„ Mining Department.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Geological Society of Italy.
„ Royal Academy.
„ Royal Geological Commission of Italy.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SALEM, MASS.—American Association for the Advancement of Science.
„ Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch, Royal Asiatic Society.
STOCKHOLM.—Geological Survey of Sweden.
STRASSBURG.—Heidelberg University.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
„ Technological Industrial and Sanitary Museum.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Geological Institute.
„ Imperial Natural History Museum.
„ Royal Academy of Vienna.
WASHINGTON.—National Bureau of Education.
„ Philosophical Society.
„ Smithsonian Institution.
„ United States Geological Survey.
WELLINGTON.—Colonial Museum and Geological Survey of New Zealand.
„ Department of Mines, New Zealand.

YOKOHAMA.—Asiatic Society of Japan.
" German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.
The Secretary of State for India.
The Governments of Bengal, Bombay, India, Madras, and Punjab
The Chief Commissioners of Assam and Burma.
The Resident at Hyderabad.
The Quartermaster-General of India, Intelligence Branch, Simla.

The Dharwar System, *the Chief* Auriferous Rock-Series *in* South India; *by* R. B. FOOTE, F.G.S., *Superintendent, Geological Survey of India*, (continued).[1]

The first half of this paper which appeared in the second part of the *Records* for last year (1888) gave a general outline of the distribution of the different great bands and minor patches of this very important and interesting rock system, and a succinct account of the main geological features presented by the two great western bands, the Dharwar-Shimoga and the Dambal-Chiknayakanhalli bands. There remain then for description the numerous outliers (III) between these two great western bands; the Sandur hills and Copper Mountain tract in the Bellary country (IV); the great eastern, or Penner-Haggari band (V); the Maski band (VI), lying north of the last, and probably connected with, another schistose band, the Bomanhal band (VII), which lies north of the Kistna and stretches away northward till it is lost under the Bhima conglomerates and the Deccan trap to the north-west of Shorapur. Lastly, the band of the Dharwars forming the Kolar gold-field will have to be dealt with (VIII).

Area remaining for description.

III.—THE OUTLIERS BETWEEN THE DHARWAR-SHIMOGA AND THE DAMBAL-CHIKNAYAKANHALLI BANDS.

These are fourteen in number and may be most conveniently enumerated by taking them from north to south—

1.—The Kunchur outlier.

This is a large outlier (8 miles west of Harpanahalli), of which, however, only the extreme north end has been visited. The hills forming the middle and southern parts are of considerable size, and, being very bare, allow of their character being recognised from long distances, *e.g.* the summit of Huchangi Drug. I could not make out, however, whether the Dharwar rocks forming the southern hills were directly connected with the northernmost extremity of the Halekal Gudda branch of the Dambal-Chiknayakanhalli band. Southward from Kunchur no outlier of Dharwar rocks occurs for 85 miles. Then in the immediate neighbourhood of the town of Banavar occurs,

Kunchur outlier.

2.—The Karadihalli Outlier.

This, as far as I traced it, consists of hornblendic and steatitic rock, resting on granite gneiss. It appeared to me of very small extent and from the aspect of the rock I am doubtful whether it should not be regarded as belonging to the gneissic rather than to the Dharwar system. Gold was obtained from its northern end by washing, and there are two or three reefs there deserving of closer prospecting.

Karadihalli outlier.

[1] See Rec. G. S. of I., Vol. XXI, p. 40.

3.—*The Tellavari Outlier.*

Tellavari outlier.

Ten miles south of Karadihalli outlier lies another, consisting of hornblendic and chloritic schists, which, like those at Karadihalli, I only doubtfully regard as of Dharwar age. Its extent I am not quite certain about, as the northern and southern ends are covered by jungle, and I had no opportunity of tracing out its boundaries. To the north I believe the schists extend only a short distance, but to the south they may possibly be connected with another small patch of auriferous rocks, 6 or 7 miles to the south-south-east, to be described further on. One of the small old workings gave a fair promise of gold from scrapings of its side, but no good-looking reefs were noticed.

4.—*The Gollarahalli Outlier.*

Gollarahalli outlier.

This very small outlier, lying 2½ miles N. N. W. of Gandasi,[1] has been accidentally omitted from the map. Very little rock is to be seen except small outcrops of hornblendic schist, which may or may not be of Dharwar age. The old workings are of great superficial extent and mostly very shallow, but the eastern side appears to deserve much deeper prospecting than had been carried out up to the time of my visit in 1887.

5.—*The Belgumba and Jalgaranhalli Outlier.*

Belgumba and Jalgaranhalli outlier.

This small outlier of Dharwar rocks, which is a very elongated ellipse in shape, measures about 5 miles by half a mile, as far as seen. The rocks seen are chloritic and hornblendic schists, which to the east of Belgumba village are traversed by two large quartz reefs, running nearly parallel with the strike of the schists, which is about S. S. E.-N. N. W. Several old workings lie on the west side of the reef ridge; they are of good size, but no reef was traceable in connection with them (in 1887), and the results of washings made there were far from promising.

At the southern end of the outlier lies the old Jalgaranhalli workings, which consist of a small and shallow pit. The surface here is very flat, and covered with an unbroken spread of soil, and the only outcrop of rock seen is a very small one of a singular hornblendic rock, of stellately felted structure. No reef was seen in the one old working, but the scrapings, when washed, gave so good a show of gold as to induce me to recommend much fuller and deeper prospection than had already taken place.

6.—*The Mallanhalli Outlier.*

Mallanhalli outlier.

This outlier lies 3½ miles further S. E. by S. and is separated from the foregoing by a spread of gneissic rocks underlying the Dharwar hornblende schists which form it. The hornblende schist is overlaid by a green micaceous gneissoid schist, and scattered about is a good deal of débris of quartzite of distinctly Dharwarian aspect. To the south the rocks are hidden by jungle and soil, and their extension has yet to be worked out.

[1] A large village (with a 3rd class traveller's bungalow), 15 miles S. W. of Tiptur railway station, on the Dharwar-Bangalore line (S. M. Railway).

The old workings consist of a large pit (unconnected with any visible reef), washings of the scrapings of which gave a moderate show of gold. A little to the north of the pit is a large reef of rather good-looking bluish and white mottled quartz, which shows for nearly a hundred yards, with a thickness of from 12 to 15 feet at the surface. No accessory minerals are seen in the quartz at the surface, but the reef certainly deserves to be well tested in depth.

7.—The Taggadurbetta and Nugihalli Outlier.

Taggadurbetta and Nugihalli outlier.

This patch of Dharwar rocks, which is of some size and importance, shows as a distinct ridge for some miles, and near its centre culminates in the very conspicuous hill after which it is named and which forms a good landmark for a long distance all around. The rocks here seen are chloritic schist, with intercalated hæmatitic bands. Two of these latter, of very massive character and considerable richness in iron, form the crest of the Taggadurbetta. Their northern extensions continue for a mile as low but conspicuous mural outcrops; they are then lost under the valley of a local stream. Their further extension has not been followed up, and it is not improbable that they may run considerably further, or even join the Mallanhalli outlier, just described, some 8 miles to the N. N. W. To the south of the summit the hæmatite beds are speedily lost sight of, as they sink down rapidly and the locally flattened top of the ridge is obscured by thick cotton soil. The summit beds have given rise to a very extensive talus of rounded and angular masses of hæmatite, which covers thickly the eastern slope of the ridge in that part. In this talus are to be seen the old workings, which consist of several very shallow pits or rather broad trenches. The few reefs seen here are of no great length or thickness. They run in the strike of the "country rock," which consists, as above mentioned, chiefly of chloritic schist. The general strike of the rocks is north and south. The reefs are very poor-looking, and the results of washing were the reverse of encouraging.

To the west of Nugihalli only chloritic schists are to be seen, but further south are beds of hæmatite schist, intercalated with the chloritic beds. Whether they are representative of the two great beds further north remains to be settled by further examination. Various pits and excavations in this part of the outlier have been regarded as old gold workings; but, I think, on perfectly insufficient evidence. Some were certainly nothing more than quarries. What appears to be the southern extremity of this outlier is a low broad knoll of chloritic schist, overlaid by a thin bed of hæmatite schist, which latter forms a wide-spread talus. Between this and the auriferous patch I call the Kempinkote outlier there is a broad belt of gneissic rocks, but it is possible that the Dharwars make a sweep round to the west, and thence trend again to the south-east, and thus join the Kempinkote patch. This, however, requires confirmation.

8.—The Kempinkote Outlier.

Kempinkote outlier.

I have called this patch of Dharwars an outlier because it appeared to me on my hasty visit to be surrounded on all sides by gneissic rocks—still it may be connected to the west and north-west

with a possible extension of the Taggadurbetta Dharwars. The rocks seen here consist of hornblendic and steatitic schists in which the great pit made by the old miners was sunk. No reef was to be seen exposed in it at the time of my visit, and but very few fragments of quartz, so few that I examined all carefully but could not find any trace of free gold; which was said to be a special feature of this old mine. A quantity of the material, scraped from the west side, where the rock is a steatitic schist gave a very rich show of gold, of fine grain and excellent colour. Judging from the great size of the mine it must at one time have been, or promised to be, very remunerative, but no evidence exists to explain why mining was discontinued. To the north-east of the great pit is a show of chloritic schists abounding in minute cubical cavities, full of reddish limonite, a product of pseudomorphism after iron pyrites.

South of the Kempinkote outlier lies a broad band of gneissic and granitoid rocks, with occasional trap dykes. The granitoid rises into the well-known Shravan Belgola hill, remarkable for having its summit carved into a huge figure of a man, 60 feet high.[1]

9.—The Bellibetta Outlier.

Bellibetta outlier.

This outlier, the northern end of which lies some 15 miles south of Kempinkote, forms a long narrow band extending southward for about 8 miles along the east side of the valley of the Hemavati river. The principal rocks seen are chloritic schists, which form the mass of Bellibetta hill (3,029′), which gives the name to this auriferous tract. The chloritic schists of Bellibetta hill are underlaid on the east by steatitic schists, on which stands the small village of Katargatta. To the north of Bellibetta hill a curiously felted hornblendic schist, with a small admixture of chlorite, occurs. The eastern side of the band of Dharwars consists mainly of talcose hornblende schists. Beds of quartzite occur here and there. The band of Dharwars forms ridges on each side of itself; both ridges are here and there broken through by the cross drainage of the country, and especially so is the western ridge. The name Bellibetta seems to include all the old workings, which are very numerous all up and down the outlier, but the principal ones are on the northern slope of the main hill, which forms the highest part of the western ridge. To what this auriferous tract owes its name of Bellibetta is not at present very clear, for no ore of silver occurs there now in quantity, or has left any traces of itself among the débris of the old workings. In Canarese, Bellibetta means the "Silver hill," and this seems to have suggested the stories which are afloat of the fabulous wealth of the place in that precious metal. I examined the old workings very carefully, but got hold of no trace of silver in any shape, though the indications of gold were decidedly favourable. The name may, I think, be rendered as "white hill" equally well as "silver hill." Several of the great brecciated quartz runs in the Bellary and Karnul Districts are called Bellagal or

[1] The figure represents Gomateswara, one of the Tirthankaras, or principal Jain Saints. The figure is said to be quite 1,000 years old, but is in excellent preservation, being most carefully guarded by the Jains. It is very remarkable that this conspicuous figure, standing some 500 feet above the surrounding plain, with no object of equal height within several miles distance, should have escaped destruction by lightning. A fine gateway a little way below the summit and cut out of the solid rock was struck, and the lintel badly sprung.

"white rock," and in the case of Bellibetta the name may merely have reference to the white colour of the great quartz reefs on the hill which are still conspicuous and must have been very much so before reduced by the extensive workings of the old miners. If silver ore ever did abound it is curious that none has remained visible at the present day. The old workings which I believe were made in quest of gold seem to have been extensive, but are so much filled up that it would appear to have been done purposely. The whole place appeared to me worthy of deep prospecting on a large scale to really test its value.

The Dharwar rocks seem to extend southward for some distance beyond the Bellibetta hill, but I had no opportunity of following them further south, and their further course in that direction is not distinctly indicated by features sufficiently strong to be traceable by sight to any great distance. Their extension has yet to be worked out.

The next auriferous tract to be considered lies about 23 miles south of Bellibetta; and about 14 miles west of Mysore city. On the map accompanying Part I of this paper I have shown three little patches (outliers?) of the auriferous rocks; but it is possible they may be connected and this connection hidden by the thick scrubby jungle which covers nearly all that part of the country. My conclusion was based on the shape of the ground, but my view of it was but very cursory. The question will have to be determined by a regular survey.

Of the three outliers just alluded to the most northerly is—

10.—The Nadapanhalli Outlier.

Nadapanhalli outlier.

This is a small patch of pale greenish brown chlorite schist, of which very little is to be seen, because of the thick soil deposits and extensive scrubby jungle. The old workings for gold occur at a point ¾ of a mile north-east by east of Nadapanhalli village. They occur mostly as shallow trenches or pits, running approximately north to south. In the southern pits the reef has been entirely removed as far as can be seen. In the northern, a good-sized reef remains but the quartz is not very promising in character. In colour it is white, but contains a fair number of cavities filled with earthy limonite probably derived from the decomposition of enclosures of chloritic mineral. Iron pyrites is of great rarity, and no other sulphides were to be found, while the washings of scrapings from the pit sides and of crushed quartz gave but a small show of gold, though it was of excellent quality.

11.—The Karimuddenhalli Outlier.

Karimuddenhalli outlier.

This patch forms, as far as I could judge, a narrow strip, about two miles long, on the top of a flattish ridge, east of Karimuddenhalli village. The rocks seen consist mainly of pale pink felspathic schists of very gneissic aspect, but associated with hornblendic and hæmatitic schists, bearing a fair resemblance to typical Dharwars elsewhere. The workings, which are very numerous, are mostly very moderate in size, but a few are large; and all seem very old, for the sides are very greatly weathered, and many good-sized trees have grown up in the bottoms, or on the sides. Many reefs are to be

seen running N.—S., E.—W., N. E.—S.W., &c., &c. Some are of good size, but all are white and hungry-looking, and of very poor promise; while the numerous washings I had made were equally unsatisfactory.

12.—The Sonnahalli Outlier.

This outlier which lies to the east of the foregoing is separated from it by a small valley, in which appears a band of unquestionably older gneissic rock, overlaid by a very trappoid hornblendic rock, the base of the Dharwars in this place. On this trappoid rest chloritic and other schists, in which are the numerous old workings which have caused this outlier to be reckoned a highly promising gold-field. The workings, judging by the extremely weathered character of the rocks forming their sides, would seem to be of great antiquity. They are also greatly overgrown with jungle. None of them are of great size or extent, and in many cases the lodes have been so entirely removed that it is only possible to guess what was the mineral mined for. The results of the numerous washings I made were not encouraging; still the real value of the place cannot be known till much deep prospecting has been carried on, and the old pits cleared out thoroughly, to show the condition of the reefs they were sunk down on.

Sonnahalli outlier.

Three large reefs are to be seen near Sonnahalli village, but none of them looks promising; the first two, which strike N. 5° W., lie half a mile east of the village, the third which runs nearly W. by N. to E. by S. lies on the north-eastern slopes of the Sonnahalli hill. This latter has been worked to some extent and apparently abandoned because of the exceeding massiveness of the reef, which is very hungry-looking.

13.—The Holgere Outlier.

This, the last of the series of outliers, will be found some 22 miles south-east of the group just described, and is formed of hornblendic schists, which may possibly be of Dharwar age and are faulted down among the surrounding gneissics. The schists are very badly exposed on the high ground south of Holgere village. In a small nullah running east into the village tank a rather fine bed of grey sub-crystallised limestone is cut across and exposed, but only for a few yards, both ends being hidden by the surface soil. The old workings are very small, and so are the visible quartz reefs, which have a nearly north to south strike. Several washings were made, but all yielded results which at best were but very middling. The recently sunk trial pits yielded no more favourable results than did the old ones, and the whole place seems worthy of but little attention.

Holgere outlier.

The shortness of my visit to Holgere prevented my ascertaining the northerly and southerly extensions of the auriferous rocks; and the country is too much covered by scrub jungle to allow of any geological features being recognised at long distances, the rocks presenting no striking outcrops.

In the last number of the Quarterly Journal of the Geological Society (Vol. XLIV, Pt. 3, August 1888) appears a short paper by Mr. G. Attwood, F.G.S., A.M., I.C.E., "Notes on some of the Auriferous Tracts of Mysore Province, Southern India,

Mr. G. Attwood's notes on some of the Auriferous tracts of Mysore.

which describes, all too briefly, two small areas belonging in part to the southern end of the Dambal-Chiknayakanhalli band of the Dharwars, and gives some "general observations, on the auriferous tracts from numerous traverses." The chief point on which I do not agree with him has reference to the geological age to be assigned to the rocks associated with the true auriferous strata. Mr. Attwood included the whole of the schistose rocks in the tracts that he examined in one great series which they certainly appear to be as seen in that part of Mysore. It is only much further to the north that the unconformity between the Dharwar schists and the older gneissics and granites can be made out; and, as I have pointed out elsewhere, some of the Dharwar schists are so gneissic in appearance that it is often extremely difficult in many sections to know where to draw the line between the two. Especially difficult is this the case in the tract occupied by the line of outliers just reviewed. Mr. Attwood, in the little sketch map at the beginning of his paper, includes in his Banavar-Honsur auriferous band many schistose rocks which I regard as belonging to the old gneissics, and he thus represents a broad continuous band where I see a discontinuous one. I am too slightly acquainted with the two areas he describes to follow his sections, which are very diagrammatic in their construction. He points out the highly broken and disturbed character of the gneissics and schists of the Mysore plateau, and then speculates on this being possibly due to the great pressure caused by the gradual elevation of the Eastern and Western Ghats; but, as the President, Dr. Blanford, pointed out in the subsequent discussion, the Western Ghats are simply a ridge left by denudation, and the same may safely be said of the section of the Eastern Ghats which forms the eastern side of the Mysore plateau. Another point requiring notice and further elucidation is Mr. Attwood's ascription of a Tertiary age to the porphyrite dykes which he met with in his "Seringapatam area." Unfortunately he has given no reasons for assigning such a comparatively recent origin to these intrusive rocks. The only porphyritic intrusion I came across in Mysore was a very beautiful warm brown, or chocolate coloured, felspar porphyry forming a large and important dyke some miles to the westward of Mr. Attwood's examples. This dyke traverses the hills immediately east of the Kattar Gatta temple, which overlooks the east end of Seringapatam Island. There was no evidence of any kind as to the age of this dyke beyond the fact of its being irrupted through the Dharwar schists after they had been brought into their present positions. It is much to be regretted that Mr. Attwood has not indicated the exact localities whence he procured the specimens microscopically examined and described by Professor Bonney in the Appendix to Mr. Attwood's paper.

Mr. Mervyn Smith's galeniferous lodes near Chittal Drug.

A fact of some interest relating to the Dambal-Chiknayakanhalli band of the Dharwars has been the discovery by Mr. Mervyn Smith (lately announced in "*Indian Engineering*") of lodes containing argentiferous galena in the neighbourhood of Chittal Drug. He specifies three: the first at the 119th milestone of the Bangalore high road, the second at the 121st milestone, on the north-eastern spur of the Jogi Maradi hill, and the third on the western slope of the same hill near the town of Chittal Drug. The galena obtained from these lodes, in the quartz of which it is distributed in patches, varies greatly in its richness of silver, some specimens being very rich. It is much to be hoped that the lodes will turn out rich enough to be worth working

profitably. It has been reported, but not on very satisfactory evidence, that both sulphide of antimony and sulphide of bismuth have been obtained in this neighbourhood. There can be no doubt that the tract around Chittal Drug is metalliferous and deserving of a very close survey.

IV.—The Sandur Hills and Copper Mountain Tract.

The Sandur and Copper Mountain synclinals.

This tract, which is of so very strange and irregular a shape that it cannot be called a band, must be considered as composed of two distinct synclinal folds, which are bracketed together, so to say, near their respective middles. Both stand out high above the general level of the country in their central parts, but sink much lower at their respective extremities, while the band of rock connecting them has also been planed away greatly by eroding forces.

The two great synclinals form respectively the Sandur hills and the Copper Mountain range, which constitute such picturesque features in the landscape for many miles to the south of the railway between Bellary and Gadag. Both synclinals run nearly north-west to south-east.

The Sandur synclinal.

The Sandur hills, which constitute the western of the two great synclinals, form a remarkably flat-topped mass, as seen either from the south-west or north-east, but at either end of the synclinal (which in plan may be compared to a broad leaf tapering rapidly towards either extremity) is approached, the ground becomes broken and to the north the hills decrease rapidly in height, and are finally lost in the plain; at the south end, the hills decrease considerably in height and the Dharwar basement beds thin out and lie raggedly on the granitic hills, which here attain some elevation. The centre of the synclinal is occupied by a considerable valley, on either side of which rise high flat-topped ridges of very nearly equal heights, though probably the western is slightly the higher and attains an elevation of 3,256 feet at the Raman Drug sanitarium. The height of the two side ridges is so equal that when looking at them from most points outside of the synclinal it is impossible to imagine the existence of the median valley by which they are separated.

Just at the broadest part, the synclinal is cut across by the Narihalla stream flowing from the south-west and continuing north-eastward to the Tungabhadra. The stream has cut two deep gorges through the great west and east ridges, which afford fine sections of the rocks forming them, and are very beautiful approaches to the town of Sandur, which lies nearly in the middle of the central valley. A third pass at the northern end of the synclinal also allows of easy access to the valley, but fails to give a useful section of the rocks in that part.

The structure of the synclinal is not so simple as it appears at first sight, for considerable inversion of the beds on the eastern side of the valley has taken place, and it is difficult to say how far westward such inversion has extended. What are probably the uppermost axial beds of the synclinal appear to dip under what are really much lower members of the system. The examination of the central valley and of the southern end of the synclinal ellipse has not yet been fully completed. To the south of the Narihalla stream the central valley is divided in two by a high rocky ridge, known as the Devadara hill, rising steeply out of the plain and running

south-east some four miles, when it joins the southern part of the western ridge, by a neck considerably lower than its own average elevation.

The Sandur section. The following section will give a correct idea of the sequence of formations met with along the Narihalla stream, beginning from the western, or Oblagundi gorge, and ending outside the eastern one, or Bhimagundi. The length of the section is a trifle over 8 miles—

1. Schist, dark-green, hornblendic (?)
2. Schist, gritty, brownish green.
3. Hæmatite rock, very thick.
4. Schist, green.
5. Hæmatite rock.
6. Schist.
7. Hæmatite rock.
8. Argillite schist, ferreous,—red, brown, and chocolate.
9. Hæmatite rock; *the gorge bed.*
10. Trap, contemporaneous.
11. Hæmatite rock.
12. Trap, contemporaneous.
13. Clay schist.
14. Trap, contemporaneous. Sandur flow.
15. Schist. } Devadara hill beds.
16. Hæmatite rock and schist. } Devadara hill beds.
17. Schist. } Devadara hill beds.
18. Trap, contemporaneous. Hoshalli flow.
19. Hæmatite rock.
20. Schist.
21. Hæmatite rock. Bhim Tirth bed.
22. Schist.
23. Hæmatite rock; *the gorge bed.*
24. Schist, with contemporaneous trap.
25. Hæmatite rock.
26. Schist.
27. Hæmatite rock.
28. Schist.
29. Hæmatite rock.
30. Schist, with contemporaneous trap.
31. Hæmatite rock. Long cliff bed.
32. Schist, with contemporaneous trap.
33. Hæmatite rock. Brecciated bed.
34. Schist.
35. Hæmatite rock. Ettinahatti bed.
36. Trap, contemporaneous.

As yet it is not possible to correlate the beds on the two sides of the synclinal, but this may be possible when they shall have been followed up round the southern extremity of the basin.

The great hæmatite beds give rise to many steep mural scarps, several of which, along the eastern side of the eastern ridge, are of great height and length, and from their vivid red colour form a splendid contrast to the patches of rich green forest remaining at their base.

This section will suffice to give a good general idea of the series of rocks forming the Sandur synclinal. The details of several other sections were given in my paper on the Geology of parts of Bellary and Anantapur Districts, and several others

will eventually be described in the forthcoming Memoir on the Bellary District. The only beds not included in the Sandur section which deserve special notice are some remarkable conglomerates exposed on the north-eastern flank of the synclinal some six or seven miles due north of Sandur town. They are of two kinds, conglomerates formed chiefly of quartz pebbles, imbedded in a tough chloritic matrix, and conglomerates of pebbles in a siliceous matrix varying in character from sandstone to perfectly jaspideous quartzite. This latter variety has been subjected to extraordinary brecciation on a great scale. In many sections the conglomerates are very distinct and fresh-looking; but as they are followed towards the north-west end of the synclinal and the beds have been tilted to higher and higher angles, a great change comes over the mass, the rock becomes strongly laminated, and the pebbles enclosed are elongated to a very remarkable extent, so much so as to look like thick and rather flattened pencils of stone. This may be specially well seen to the east of Jambanatkonda, the fine peak to the eastward of Hospet.

Conglomerates in the Joga ravine.

Alteration of conglomerates by pressure.

The most remarkable feature of the Sandur synclinal is the immense development of the hæmatitic beds and their extraordinary richness in iron of excellent quality. Only the fuel is wanting for this region to become one of the great iron-yielding centres of the world. The richness in iron of the hæmatite beds varies greatly, the beds varying from almost pure quartzites with hardly any hæmatitic laminæ to massive, almost pure steel-grey, metallic rock of intense hardness. An example of the latter on a great scale is to be seen south of the hamlet of Kummataravu (Combudhurroo of sheet 59) about six miles north-west of the extreme south of the synclinal. At other places the beds run into a poorly or richly ferruginous argillite, as the case may be; at others again the rock is highly jaspideous in character. This jaspideous variety is specially developed on the north-eastern side of the synclinal at and around the little ruined hill fort of Timappaghur (Timanghur of sheet 58) and in the Ramgor ravine and several others opening out to the northward. In the Ramgor ravine splendid ribbon jasper—banded vivid red and rich grey—forms huge cliffs 200 feet, or possibly more, in height. Superb specimens of this wonderfully beautiful rock are to be procured of almost any size. Along the western edge of the synclinal this highly jaspideous character of the rock is less strikingly displayed; the hæmatite is of a more earthy character, and in its weathering gives rise to much local pseudo-lateritic breccia, which is very characteristic of the plateau on which the little sanitarium of Raman Drug stands.

Hæmatitic rocks.

Ribbon jasper rock.

Ferruginous surface breccias.

Schists and argillites are more commonly seen here, and one or more of these latter, which are exposed in the cuttings made by the ghât which descends the western slope from Raman Drug to Narraindeverkerra, contains manganiferous concretionary nodules in considerable quantities. The more earthy nature of the hæmatites on this side of the mountains has given rise to a huge talus along their base, so great as completely to conceal the boundary between the Dharwars and the granitics for some 13 miles. Much of this talus is of very rich quality, but no use is made of the ore.

Schists and argillites.

The hæmatite ore smelted at Kamalapur and then made into the large bowl-shaped sugar-boilers, so largely used in sugar manufacture in the Tungabhadra Valley, is quarried on the spur north-west of Jambanát Konda.

The ore is a very rich reddish-grey metallic variety, and yields iron of excellent quality, and the Kamalapur sugar-boilers are highly esteemed in that region.

I came across no old workings or mines, but such may exist nevertheless hidden in the jungle which obscures the hillsides greatly in some places.

The trap area connecting the Sandur and Copper Mountain synclinals.

As seen in the section given above the lowest bed of the Dharwar system east of the synclinal is a contemporaneous trap which spreads across the space between the Sandur and the Copper Mountain, and forms a considerable tract mainly occupied by rounded hills, rising to 300 or 400 feet above the surrounding plain. The whole is not one unbroken flow, for here and there small deposits of schist, hæmatite, and in one case—to the south of Toranagal (Tornagul)—of crystalline limestone, show that intervals must have occurred when sedimentation began to occur again between the outpouring of the several flows.

The trap, macroscopically viewed, is a diorite of medium texture and black colour. Here and there it is coarse-grained in texture. A slight tendency to prismatic jointing is not uncommon, but the prisms are rarely more than a foot in length and rude in shape. This trap forms the base of the greater part of the south side of the Copper Mountain synclinal, but is over-lapped at the ends, *e.g.* to the north-east of Toranagal, where a hæmatite bed rests directly and undisturbedly on the very hummocky surface of the coarse porphyritic granite.

The Copper Mountain synclinal.

The Copper Mountain synclinal offers a much less interesting succession of rocks than does the Sandur synclinal. This is partly owing to the fact that the sections are much less perfect, rendering it far from easy to correlate the several members of the two synclinals, or even to feel perfectly certain as to the identity of the principal beds at the opposite ends of the synclinal. This is a difficulty which always exists in areas where the strata have been much contorted and fractured, and contain neither fossils nor minerals whose distribution is sufficiently special to admit of their being used to determine horizons.

Central section.

The most interesting section across this narrow and greatly squeezed-up synclinal is to be traced from the great tank at Avinmudagu north-eastward for a distance of about $5\frac{1}{2}$ miles very nearly about the middle of the synclinal. The succession obtaining here is as follows:—

South-west Wall of Synclinal.	*North-east Wall of Synclinal.*
Hæmatite quartzite.	Hæmatite quartzite.
Schists, hornblendic, &c.	Schists, hornblendic.
Hæmatite quartzite.	Hæmatite quartzite.
Schists, hornblendic, &c.	Schists, hornblendic.
Hæmatite quartzite.	Hæmatite quartzite.
Schists, hornblendic.	Schists, hornblendic.
Hæmatite quartzite.	Hæmatite quartzite.
Schists, hornblendic, &c.	Schists—black and green hornblendic, &c., a great thickness, base not seen locally.
Trap.	
Schists.	
Granite gneiss.	

The beds forming the north-east wall of the synclinal are slightly inverted, while those of the centre are vertical and those of the south-west wall have a very high northerly dip. I cannot help thinking that only the basal part of this exceedingly deep synclinal fold now remains; the upper part, which included many of the beds represented in the Sandur synclinal having been bodily denuded away; in fact only about half of the whole series has been allowed to remain. The hornblendic schists alternating with the hæmatite beds appear to represent the contemporaneous traps which form so striking a feature in the north-eastern wall of the Sandur synclinals. Owing to their having undergone far greater pressure in the Copper Mountain synclinal, the trap-flows would appear to have been converted into hornblendic schists.

"Schistification" of traps.

At the eastern end of the synclinal, where the compression was much less, as shown by the much smaller angle of dip of the hæmatites, the traps have only been partially schistified (if such a word is allowable), and appear variously as nearly unaltered trap, as a trappoid of semi-schistose character, and as true schists, but generally cut up into small masses by an infinite number of small joint planes often at right angles to the great cleavage planes.

Argillites and jaspers rare.

The argillitic form of the hæmatite is rarely seen in the Copper Mountain synclinal; so also the jaspideous and bright coloured variety of the quartzitic form. The beds on the whole are poor in iron as compared to those in the Sandur synclinal.

The name of the synclinal is that by which its highest summit is known to the European residents of Bellary, and was derived from the fact that copper mines were said to have been opened on the south flank of the mountain by Tippu Sultan, but to have been speedily abandoned because unproductive. I did not see them myself, and my guides on both occasions that I climbed the mountain knew, or affected to know, nothing of them; but I hope to re-examine the south flank much more fully than I have yet done and shall probably hit upon the small pits then excavated.

The highest summit of the Copper Mountain, known to the natives as the Sugadevi-ammabetta after a local goddess, attains a height of 3,140 feet. It is covered by a local breccia of pseudo-laterite, derived from the decomposition of the great hæmatite beds which compose it.

Northern end of synclinal.

The northern extremity of the synclinal is very obscure; of the great hæmatite beds which alone admit of clear stratigraphical determination, the eastern series dies out—or more probably is cut off by an obscure fault at the north end of the line of hills which they form; the western series thins out rapidly and is lost to sight about a mile to the north of Daroji village, and the underlying hornblendic schists have been so much eroded that they are only to be traced as a thin narrow band, which stops short about 5 miles south of the Tungabhadra river.

Eastern end of synclinal.

The eastern end of the synclinal extends some 10 miles east by south of the Copper Mountain itself and then ends abruptly, the whole series having been denuded away. It will, I expect, be found that a band of Dharwar rock re-appears some 7 or 8 miles further to the south-east in the unsurveyed area east of the Haggari river; for I noticed

(from a hill a few miles west of Uruva Konda) a tract of slightly elevated ground stretching away south, which had a distinctly non-gneissic aspect.

V.—THE PENNER-HAGGARI BAND.

It will be seen on reference to the map that there is a trifling break in the central part of this band; this was not known when I chose the name for the band, but the break is so trifling, and the connection of the beds on either side so absolutely distinct, that I will not change the name.

Divisions of the band.

For convenience of description, however, I will speak of the north-western part of the band as the Hunugunda division and of the south-western as the Penner division.

Yerkal bay.

The extreme north-westerly outcrop of this band of Dharwars occurs at Todihal, a village on the right bank of the Kistna, as a show of hornblendic schist with intercalated beds of pale, pinkish white talcose schists. The southern side of this Dharwar outlier is bounded by the overlying basement quartzites of the lower Kaládgi series, which here forms the Bilgi hills. The Kaládgi beds here form a synclinal fold, beneath which the Dharwar rocks are hidden, but re-appear about 8 miles to the south-east and form a deep bay between two diverging scarps of the lower Kaládgi quartzites and conglomerates. The bay, which I will call the Yerkal bay, has been formed by the denudation of the western end of an important anticlinal fold of the Kaládgi series, which rested on the upturned edges of the chloritic, hornblendic, and hæmatitic beds here composing the Dharwar series. The chloritic and hornblendic series have been greatly denuded themselves and a deep valley excavated in them, out of which several beds of hæmatitic quartzite and hard schist stand out as prominent ridges, but which gradually sink down to the eastward. This erosion valley is itself crossed nearly at right angles by the Ghatprabbha river flowing northward to the Kistna. The river flows through two gorges cut through the south and north scarps of the Kaládgi basement quartzites and conglomerates.

Gorges of the Ghatprabbha.

The southern gorge[1] is of no special interest, but the northern, or Yerkal gorge,[2] is noteworthy from the great cliff of hæmatite schist formed by the northernmost bed of that rock just south of the Kaládgi scarp, which has locally sunk into a low saddle. The Dharwar rocks are very ill-seen in the centre and on the south side of the erosion valley, but on the northern side they are fairly exposed for some 5 or 6 miles, when the hæmatitic ridges sink down and are lost under the general spread of cotton soil which covers everything for miles around. They rise over the surface in low hills here and there near Byramatti and Hamblikop, and then sink down again and are lost sight of as they approach the Malprabbha river. They make no show in the bed of the river and do not re-appear again till 5 or 6 miles further on, when they crop up conspicuously in the Hunugunda ridge, which is about two miles in length. Here they are schistose in character and not rich in iron. A little to the south-east

[1] The southern gorge lies about two miles north-east of the important town of Bagulkota, and is traversed by the Eastern Deccan railway.

[2] The rock forming the cliff at Yerkal is much more a jaspideous quartzite than a schist, into which however it passes both to the east and west.

of the town they again sink down under the cotton soil spread to re-appear another five miles to the south-east near Tumbigi, from which they may be traced in a line of poorly ferruginous rather argillaceous schistose hills past Kandagal out of the Bombay Presidency into the Raichur Doab, the portion of His Highness the Nizam's dominion lying between the Kistna and Tungabhadra rivers. Here the character of the country changes and the nearly dead level plain is replaced by an undulating and in parts hilly tract. The sections become much better and several other outcrops of hæmatitic rock appear to the north of the Hunugunda series we have been following south-eastward from Yerkal gorge. Near Meyrudodi, 6 miles north-north-west of Tawaragiri, the hæmatitic rocks rise into a high and conspicuous ridge of richly ferruginous quartzite which continues for several miles, when the beds become poor and soft, and are lost sight of for a few miles, but again become rich in iron and form well-marked ridgy outcrops, which rise finally into the high ridge of the Iiadigudda, the highest point in that region, and fully 800 or 900 feet above the surrounding plain. The beds here are very rich in hæmatite; and in former times, when charcoal was cheap, before the destruction of the forests was complete, much iron was manufactured and found a ready sale to the Hyderabad armourers, being of very excellent quality. The reckless destruction of the forests raised the price of charcoal so greatly that the iron-smelting industry was utterly ruined many years ago. Within the present year the prospecting officers of the Hyderabad (Deccan) Company have discovered some very extensive old mines on the Iiadigudda, which are supposed to have been made in quest of gold. About 3 miles south-east of Iiadigudda the beds have again become poor and the series cannot be traced any further.

Meyrudodi and Iiadigudda hæmatites.

We must now retrace our steps some 40 odd miles to the west-north-west, to the most easterly point of the main Kaládgi area. Here, about 2½ miles west of the village of Amingarh, is a remarkable group of hæmatitic beds of great beauty and deserving of attention from the great amount of contortion they have undergone. They show a subsidiary degree of minute crumpling besides the great curves into which they have been squeezed by great lateral thrusts, resulting in the production of numerous "vandykes," in which the variations in colour of the different jaspideous and ferruginous laminæ are beautifully displayed. The slightly ferruginous jaspideous laminæ vary in their colour from pinkish to almost pure scarlet, and form striking contrasts with the white or pale drab of the non-ferruginous siliceous laminæ, or the purplish, semi-metallic grey of the richly hæmatitic laminæ.

Amingarh hæmatites.

The siliceous laminæ are very fine grained in texture and often as semi-vitreous as very fine grained quartzites, and frequently weather to a glossy jaspideous surface, instead of becoming dull and earthy looking. The contortions are best seen to the west of the small ghat by the high road to Kaládgi, which crosses the hills 2½ miles west of Amingarh. The rocks here are generally very rich in hæmatite and the red jaspideous bands are very numerous, so that the great curves and minor vandykes in which the beds stand out from the hillsides present a very remarkable, and, when lit up by the morning sun, a very beautiful appearance.

There are other displays of hæmatitic beds both west of that just described and

to the S. and E. S. E. of Amingarh, but they offer no specially noteworthy features. As a rule, they are much less rich in iron than the above described.

Jamalapur hæmatites.

Another group of hæmatitic beds of some importance lies to the south of the main ridge at Jamalapur some 4 miles south-west by south of Meyrudodi Trigonometrical station hill above referred to (p. 30).

Survey of Hunugunda division insufficiently close.

The intimate geological structure of the Hunugunda division of this great Dharwar band was not worked out as fully as desirable; the time at my disposal did not admit of it. The country was traversed in rapid marches just close enough to ascertain the existence or non-existence of possible outlying basins of the Indian carboniferous rocks which might have been spared by the denuding agencies that played such havoc with the Lower and Upper Gondwana formations on the eastern side of the peninsula. The schists were regarded as belonging to the great gneissic group, to a close examination of which time was not to be devoted unless any special metallic wealth demanded it. The connection between the schistose bands and any of the auriferous tracts was not known till a couple of years later, when I had visited and explored the auriferous northern end of the Dharwar-Shimoga band and the Dambal goldfield of the Dambal-Chiknayakanhalli band, but after that no opportunity occurred of my revisiting any part of the north-western, or Hunugunda, division of the Penner-Haggari Dharwar band.

Schistose beds.

The greater part of the Hunugunda division, consisting, as it does, of comparatively soft chloritic and hornblendic schists has been worn down to a level plain, the greater part of which is obscured by cotton soil. Chloritic schists are to be seen largely exposed in a few localities, as at Timapur (Teemehpoor), 3 miles north-west of Hunugunda (Bijapur District), and at Somulapur, 10 miles south-west of Mudgal, in the Nizam's territory. The colour of these schists is predominantly a delicate pale green; dark green varieties are less common, but are also to be met with. The chloritic schist tracts are characterised by the absence of all hills of any size or elevation, but are much cut up on a small scale by watercourses.

Hornblendic schists are also common in parts of the band, as to the south-west and south of Hunugunda at distances of 10 and 5 miles respectively; and elsewhere are associated with, and strike parallel to, the more conspicuous hæmatitic bands.

Trap flow area at east end of Hunugunda division.

To the east of Iiadigudda the hæmatites become very much less important, and many strongly hornblendic massive spreads of rock appear, presenting all the appearance of being truly contemporaneous trapflows. From Tawaragiri the width of the band of Dharwars decreases rapidly. At Kulumangi (7 miles to the east-south-east) it measures only 3 miles, as against 6 at Tawaragiri. It goes on decreasing in width as followed south-eastward, and about 5½ miles from Kulumangi has narrowed away completely and disappears about a mile south-west of Mailapur (Mylapoor).

Penner division of the band.

Four miles to the E. by S., traces of Dharwars re-appear but form only an extremely narrow spit at first; this widens, however, as followed south-eastward past the large village of Karatugi. The northern boundary of the band runs on hence to, and across,

the Tungabhadra in an east-south-east direction, while the southern boundary trends south-east and south in a wavy line to the river, which it crosses in a south-west direction and joins on to a very irregular patch of Dharwars lying on both sides of the river and extending up its valley as far as the town of Kampli (Kumply).

The sinuosity of the boundary of this patch is such that where the main band crosses the Tungabhadra at Naddavi it is barely 2½ miles wide.

The principal rocks seen on the Doab side of the Tungabhadra are trappoids and traps, which form the greater part of the low-lying parts of the bands, but are very ill seen, owing to the thick and continuous spreads of cotton soil obscuring the surface nearly everywhere. Two or three poor beds of hæmatite are exposed in the line of low hills which run just within the northern boundary, and curve round east-south-east into the small hill west of Nandihalli and north of Naddavi, at which village they cross the Tungabhadra. Argillites, with some flaggy sandstones, here and there approximating to quartzite, occur in the centre of the valley north of the Murigudda (Moorygooda) ridge, a bold ridge with fine cliffs on its southern scarp rising some 600 to 700 feet above the plain. The flanks are nearly everywhere thickly covered by talus; but at one place, a little to the south-west of the Trigonometrical station hill, a rain gully cuts into beds of green and pale green chloritic schist.

Murigudda brecciated quartz run.

The main mass of the ridge consists of beds (apparently two in number) of massive quartzose rock, with much quasi-brecciation. On the northern side of the ridge this rock, when seen from a little distance, bears a great likeness to a true quartzite, its thick bed dipping northward, but close at hand the rock has a close resemblance to the ordinary brecciated quartz characteristic of so many of the great runs traversing this part of the Southern Deccan. I hope to be able to get some light on this point by a microscopic examination of sections from different parts of the ridge. A very similar rock, probably an extension of the Murigudda ridge, forms a small hill, 2 miles east of Karatugi. Here again the rock looks in many respects more like an altered quartzite than a true vein quartz.

The Kampli patch.

The rock forming the patch extending up the Tungabhadra valley towards Kampli consists largely of trap, trappoid, and hornblendic and chloritic schists, with a few small hæmatitic beds. The schists are in many places cut through by intrusive veins of pegmatoid granite. Some of these are particularly well seen in the left bank in the Yeeminganur nullah, 6 miles east of Kampli town. Some of the granites occurring among the schists in this quarter appear to be contemporaneous. Good examples of such are to be seen in the banks of a small nullah draining the high ground immediately north-east of Kampli; also, on a somewhat larger scale in the banks of a nullah, which falls into the Tungabhadra, 4½ miles north-east of Kampli. These granite flows are best seen where the road from Kampli to Itugi crosses the nullah.

Contemporaneous granites.

Naddavi hæmatite.

To return to the place where the band crosses the Tungabhadra, the beds seen here are chiefly dark hornblendic schists and trappoids, but immediately west of the village of Naddavi is a fair band of hæmatite schist, which is doubtless a southerly continuation of the band forming the crest of the Nandihalli hill above referred to. The beds show much lateral

contortion to have taken place. The strike is parallel with the general course of the band.

For many miles south-south-eastward from the river, the course of the band is greatly obscured by the continuous cotton soil spreads which cover the country. It is only here and there that an unusually hard bed of rock stands up over the surface and forms an outcrop. As a rule, the presence and nature of the rocks can only be ascertained by laboriously hunting for outcrops in the larger streams draining the surface. Among the few features of interest in the course of the band between the Tungabhadra and the Haggari are the two important hæmatite bands forming the Sindigiri hills. They are fairly rich in iron, and here and there quite jaspideous in texture. Two miles south-east of their southern extremity rises a ridge of very slightly hæmatitic quartzite, which, though low (about 100′ high over the plain), is remarkable for its bare and rocky character and very artificial appearance, due to the peculiar nature of the jointing. The last noteworthy feature to be seen west of the Haggari is a low bare hill of very black trappoid, immediately north of the Bellary branch of the Southern Mahratta Railway and about 4 miles east of Bellary. All the rest of the band is hidden under cotton soil, a few nullah sections excepted. No outcrop of the Dharwars shows through the alluvium of the Haggari, and on the east (right) bank of the river the country resumes the same character of a nearly level plain, out of which only a few low hills rise at long intervals. Two lines of high ground occur here; the northern one consisting of poor hæmatitic beds, with associated schists and argillites, which form three hills, two at Joladarashi and a third, 1½ mile to the south-east, on which stands the village of Chel Gurki (Chailgoorky).[1] The strike of these beds is south-easterly, but at a very little distance east of Chel Gurki they sink down and are lost under the cotton soil.

Sindigiri hæmatites.

Bevinhalli trappoid hill.

Chel Gurki hæmatites.

The southern line of hills is divided in two by a broad saddle. The hills are low (100′—150′) and rocky, and would not deserve mention, but that they consist of a diorite (?) of extraordinary character. This rock shows a green hornblendic matrix, full of whitish pink, or whitish enclosures of felspar (Orthoclase ?) approximately spherical in shape, and generally from ¾ to 1 inch in diameter. The number of enclosures, which never show any crystal faces, is very great and must often form fully a 4th of the whole mass, which is intensely hard and tough. At a little distance the rock often resembles a puddingstone, for which indeed I mistook it at first sight. The mass of the hills is made up of three great dykes of this very remarkable form of trap. A small dyke of the same kind is also to be seen along the south side of the Madras-Bellary high road, a couple of miles east of the ford over the Haggari.

Dykes of coarse diorite.

When exposed in nullah sections the main mass of the band is seen to be made up of hornblendic and chloritic bands.

Penner division mostly schistose.

About 8 miles south-west from Bantanahal railway station is a low ridge, in

[1] South of Virapur Railway Station.

which beds of chloritic schist alternate with beds of jaspideous hæmatitic quartzites. These disappear to the east under the cotton soil, but it is not unlikely that to the west they may really be continuous with the Chel Gurki beds above referred to. Further to the south-east little is seen because of the cotton soil, but where outcrops occur they mostly show trappoids or hornblendic schists. The character of the country continues unchanged till the basin of the Haggari is left, but then the slowly undulating plains are replaced by broken rocky country, traversed by numerous large and important dykes of diorite. The band consists here mainly of hornblendic and chlorite schists, which extend to and across the Penner, beyond which the band has been followed for a distance of 15 miles by my colleague Mr. Lake, who found them forming a clear and simple synclinal just south of the river, consisting of alternations of trap flows and schists. To the eastward of the main band lie a considerable number of outlying patches of Dharwars which show signs of having been greatly broken up by the agencies which crumpled up the whole system. Its further course appears to be southerly, and its connection with yet more southerly occurrences of Dharwars has to be worked out. Schists, apparently of Dharwar age, are reported from the south of the Anantapur District, and also from Pargarh in Northern Mysore.

Hilly tract in the Penner basin.

Probable extensions of the Penner Haggari band.

A show of schists of Dharwar aspect was met with by Dr. W. King a little to the south of where the Chitravati river cuts through the hill ridge forming the base of the Kadapa basin, 30 miles south-east of Anantapur town, but was not followed any further. This schist patch is said to be the extreme north extension of the Kolar goldfield band, a statement which will, I expect, very probably be verified when the tract of country lying between the two points comes to be surveyed.

I did not meet with any old workings of any sort in the Penner division of the band, nor did I hear of any on enquiry, but I came across no one likely to give me any useful information on this point.

VI.—THE MASKI BAND.

This important band is called after the large village of Maski (Mooski of sheet 58), which stands on the western side of its southern half. No other place of any importance or note stands on this band of Dharwars after which it could have been more fitly named. The band is very irregular in shape, and a much better idea of it will be got from inspecting the map which accompanied Part I than by any description that could be given. Its southern extremity lies about 3 miles north-west of the Tungabhadra in Lat. N. 15° 42″ and its northern lies about 43 miles to the north by 5° west, in Lat. N. 16° 21″, and about 4 miles south of the Kistna. There is some reason to believe that its extreme north-western extremity continues up north and crosses the Kistna; this point, however, requires further examination, for there is in the immediate vicinity another band of hornblendic schists belonging to a gneissic series older than the Dharwars. When I visited that quarter in 1870 I was not in a position to distinguish between the two series.

Its extent and shape.

The northern half of the Maski band is essentially hilly, the hills being mostly low and rounded like downs, with a generally smooth surface, extensively covered with cotton soil, which is rather unusual, for cotton soil, as a rule, affects only level tracts of country and disappears from all but the very gentlest slopes.

Northern half of band hilly.

The southern half is very flat and can boast of only a couple of hills. Except on these two hills very few outcrops are seen anywhere over the southern half. The predominating rock throughout the band is a schistose, black, hornblendic trappoid, passing locally into unaltered contemporaneous trap or into true hornblendic schist, as the case may be. A few rather poor hæmatitic bands occur in the southern part of the northern half, and again in the southern half to the north-north-east of Sindunur. Near Wandalli, in the centre of the broadest part of the north half is a noteworthy example of an altered conglomerate, with a siliceous matrix. The enclosed pebbles, which are not very numerous, have been squeezed into long and rather flattened cigar, or pencil-shaped bodies. Chloritic schists are well developed locally but to nothing like the same extent as the hornblendic schists.

Southern half very flat.

Hornblendic rocks predominant.

In most parts of the band the bedding of the rocks is parallel to the strike of the band, but local deviations of strike occur, especially in the broad part of the northern half, and the deviation in this latter case has been followed by the quartz reefs, which there occur in numbers.

Prevalent strike.

This Maski band is at the present time being energetically prospected by the prospecting staff of the Hyderabad (Deccan) Company, headed by Mr. W. P. Stephenson, assisted by Messrs. W. K. Cherry, Molony, and Temby. They have discovered very large numbers of old workings, many of them of considerable size and depth, proving beyond a doubt that a large and important gold mining industry existed here a long time since, probably in the peaceful times before the Mussalman invasions. Many of the workings had evidently been deliberately filled up, probably to conceal them from the enemy.

Old workings numerous and important in the northern parts.

Dr. King and I paid a flying visit to this goldfield quite lately and were shown several very important old workings near Wandalli and Topuldodi to the north of Kavital (Kautala of the country people), besides numbers of lesser ones. The workings have in many cases been followed down to between 40 and 50 feet, but then water comes in and prevents further exploration till pumps can be rigged up to drain them. This will be done very shortly, and the old workings will then be bottomed, when it will become possible to reach the undisturbed lodes and ascertain their real value. In the meantime encouraging shows of gold have been obtained from crushings of bits of the lodes left as props to the shaft walls.

We saw two good groups of "mullockers," or the small mortars in the rock in which the old miners pounded up the ore, or "mullock." One of these, close to the Topuldodi camp, showed the ordinary small mortars rather larger and deeper than half a cricket ball, with several larger ones, like inverted dish-covers. The other group, about a mile north-west of the

"Mullockers."

Wandalli camp, shows large shallow saucer-like hollows in the solid, tough trappoid.

Granite crushers.

In these the ore was crushed, not by hand, but by working great rounded granite crushers, between half a ton and a ton in weight. The size of these crushers is so great that they must have been worked with some kind of framework by which to get leverage to move them easily. A considerable number of these great crushers are to be seen, and several lie in their proper hollows. They must have been brought from several miles distance and at no small expenditure of labour. It is abundantly evident that a great mining industry was once in progress in this Dharwar band; and there are at present good grounds for hoping that the reefs to be reached may, as in the case of several of the Kolar mines, turn out really rich enough to be profitably worked in European fashion.

Other old workings.

The mines just referred to are all in the broad part of the northern half, but numerous other workings occur in the southern part of the northern half near to, and south of, the Lingsugur-Raichur high road. Some of these also are important from their size and depth, and may lead down to valuable lodes. I came across only one of these workings, near Boodimir, and that contained water at a depth of about 20 or 30 feet down on an incline. I could not get hold of any lode to find out the nature of the mineral looked for, nor could I find out on enquiry of the people what the mine had been sunk for.

A curious proof of the utter oblivion these mines seem to have fallen into among the people around is the fact that their existence was unknown to Colonel Meadows Taylor, who resided near for many years, and gave up much time to the geology and archæology of the country, and was moreover a perfect master of the vernacular, and on the most friendly terms with the inhabitants.

Billudumurudi outlier magnetite bed.

Two or three miles westward of Maski town lies a short and narrow band of schistose rock, which from its position would appear to be an outlier of the Maski band; but which I feel a little doubtful about because of the schists which form it being associated with one or two beds of poor magnetic iron. Magnetic iron is a decidedly uncommon rock in this part of the country, though extremely common further south and east in the Salem, Coimbatore, and Nellore Districts, and in all these cases the magnetite beds are distinctly gneissic in their age and association. The hornblendic schists associated with this magnetic iron are not unlike some of the Dharwars, and gold was obtained from them by the Deccan Company's prospectors at Billudumurudi, the highest hill in the little band. If these beds be really of Dharwar age it is the only case to my knowledge of a magnetic iron belonging to that system; all other iron beds associated with it being hæmatitic.

VII.—The Bomanhal Schist Band.

This band stretches from near the left bank of the Kistna west of Shorapur in a N. 5° W. direction some 20 odd miles, till it is lost sight of under the great cotton soil spread which lies on the divide between the basins of the Kistna and Bhima. The southern end is hidden by the alluvium of the large Bomanhal nullah. I call

Why so named.

this band after the village of Bomanhal, which stands on its southern end, and is noted for having been a favourite abode

of Colonel Meadows Taylor, C.S.I., the distinguished author, when Resident with the Rajah of Shorapur. His house on the top of the hill overlooking the great tank commands a fine view all along the band of schists, the eastern half of which occupies the valley of the Bomanhal nullah, while the western half forms a well marked succession of hills and downs. The band has an average width of about 3 miles. The schists composing it are mainly hornblendic, and there can, I think, be no doubt as to the Dharwar age of this band. This question will soon be decided, as Mr. Stephenson and his prospecting officers are to attack the band ere long. From the general impression of the band as a whole which remains in my mind I shall be surprised if it does not turn out an important mineral region.

The Saggar band.

Between 10 and 12 miles east of the Bomanhal band is another band of hornblendic rocks which I did not show in the map in Part I, being rather doubtful whether it should not be regarded as belonging to the older gneissics, like the hornblendic band immediately north of Lingsugur. A further study of my field maps, however, leads me to think it should be regarded as of Dharwar age and should as such have been shown in the map. If this is right, it should be called the Saggar band, or outlier, from the small town of that name which stands on it. The main mass of it lies between Saggar and Shorapur town. A narrow band of hornblendic beds, probably a continuation of the Saggar bands, was mapped by Dr. King as curving round the small granite gneiss massif of Shahpur, which lies immediately north-east of Saggar town.

VIII.—THE KOLAR GOLDFIELD BAND.

Last in the order of description, but first really in practical importance, is the narrow band of Dharwars known as the Kolar goldfield, which lies some 40 miles east of Bangalore. The great success attained at a good number of the mines now being worked there has proved beyond all cavil that gold does exist in richly paying quantity in many of the lodes running through the Dharwar schists, and I for one firmly believe that lodes of equal richness will be found in other tracts in which similar geological conditions prevail. It is remarkable what good judgment the old miners had in these matters; possessed of no real scientific knowledge they nevertheless succeeded in gaining great practical experience as to the nature of the rocks and conditions of position most favourable to successful extraction of the gold when found. Where their old workings were most extensive and deep, there their modern successors have also, as a rule, been most successful, when they descended to levels the old miners were unable to reach from the insufficiency of their mechanical appliances.

The Kolar band a true synclinal.

In many parts of the other schistose bands it is impossible, either from the obscure and confused position the rocks occupy or from the very small show they make on the surface, to say how they really lie. In the Kolar band near the mines, this is not so, for there it is clear that the schists are disposed in a deep narrow synclinal fold. This fold rises in parts somewhat over the general level of the surrounding granitoid country and, nearly throughout the western side of the band, occupies a higher level than the eastern.

The dip of the rocks forming the basement of the band and therefore the boundaries of the synclinal, is easily traced on both sides; but not so the dip of the axial beds of the fold, the uppermost members in fact, for they have been so altered by the great pressure which gave rise to the synclinal that an irregular cleavage system was set up which entirely masks the original planes of bedding. Extensive minute jointing has also supervened to increase the alteration changes. The lines of bedding are completely obliterated, and it was (at the time of my visit) impossible to decide from the sections seen whether the central axis of the synclinal represents one great acute fold or a series of minor ones in small vandykes. The great petrological similarity of the strata forming the axial part of the synclinal makes it all the harder to unravel the difficulty. The various sections in the shafts being sunk at that time (1881) threw no light on the subject, and I do not know whether subsequent observers have been able to settle this point.

Axial beds much altered by pressure.

The basement bed of the fold appears to be the hæmatitic quartzite which forms on the western side of the synclinal and rises into the Walagamada hill ridge. The bedding of this is often vertical and much contorted in places. The texture of the rock varies from a highly, jaspideous quartzite to a schisty sandstone. The beauty of the vandykes, crumplings, and brecciations of this rock in the Walagamada Konda is very remarkable. On the eastern side of the fold the hæmatite quartzite is much less clearly developed, except in the south-east part of the goldfield, where it forms the main mass of the Yerra Konda Trigonometrical station hill. Overlying the Walagamada quartzites are chloritic schists, on which rests a great thickness of hornblendic schists and trappoids, which make up the central mass of the synclinal. To the south of the goldfield tract the synclinal becomes pinched and dies out in long narrow strips which run down into the Krishnagiri taluq. These have been investigated by Mr. Bosworth Smith, Mineralogist to the Madras Government, but his report on them is not yet available.

The basement bed.

The Kolar band has been examined by me only for a little distance north of the goldfield, but several prospectors claim to have followed it up north for a long way and speak very highly of its promising appearance. One prospector informed me he had traced it continuously northward till it passed under the basement of the Kadapa rocks near the gorge of the Chitravati. If this be so he must have joined it on to the schistose patch discovered by Dr. King and mentioned above at page 34. Another, but less reliable, observer told me the band stretched away more to the east of north and passed close to Maddanapalli in the Kadapa District. It is hardly probable that the band maintains itself as a simple synclinal fold for many miles north of the goldfield, and it will be curious to ascertain what position the beds then assume.

It should be mentioned, in conclusion, that the position of the rich reefs in the goldfield is rather to the eastward of the axis of the synclinal. In this respect the mines lying in the same line as the Mysore, Urigam, and Nandidrug mines are much the best off; the reefs further east have so far been less productive and those to the west of the axis seem to be decidedly poorer. The best quartz is decidedly blue and contains but little pyrites. In only one mine were arsenical pyrites said to be injuriously common, and to necessitate special treatment of the ore.

It is not in accordance with mining experience elsewhere that every venture should succeed, but the results already obtained are abundantly good enough to encourage sensible people to proceed with care and forethought to open other mines in the Dharwar rocks.

Eruptive Rocks in the Dharwar areas.

The Peninsular system of trap dykes.

Many intrusive rocks occur in the Dharwar areas, but the most remarkable are the dykes of what may be called the great Peninsular trap system, from its general development all over South India, in many parts of which it forms the most remarkable feature in the country, for example in North Arcot, South Kadapa, and the east part of Anantapur. Such an extraordinary network of dykes of dioritic trap of all sizes, but mostly very large, is, I believe, quite unparalleled elsewhere, but certainly so in India. The majority of these dykes were intruded after the formation of the Dharwar rocks, and many of them are to be seen cutting though the schists and quartzites. They belong to the period intervening between the crumpling up of the Dharwars and the deposition of the Kadapa beds. The few dykes found intruded into the Kadapas belong to a newer and different looking series.

Pegmatite veins.

Large veins of pegmatite cut the Dharwars here and there, as at the place where the extension of the Sundur synclinal crosses the Tungabhadra and in the Kampli patch before referred to (page 32).

The porphyrites occurring in the Dharwars in the neighbourhood of Seringapatam are also noteworthy intrusive formations.

Brecciated quartz runs.

Lastly come the brecciated quartz runs, such as that forming the Murrigudda in the Penner-Haggari band, close to the Tungabhadra; their true nature and their relation to the Dharwars have yet to be worked out.

Notes on the Wajra Karur Diamonds, *and on* M. Chaper's alleged discovery of diamonds in pegmatite near that place; *by* R. BRUCE FOOTE, F.G.S., *Superintendent, Geological Survey of India.*

Fresh attention having been drawn to the subject of the occurrence of diamonds at Wajra Karur in the Anantapur District by the starting not very long since of a Joint Stock Company to work the supposed matrix there, it may not be inopportune to offer some further remarks on the subject, as they appear to throw some more light upon this very interesting question. I wish also to make some comments on an alleged discovery near Wajra Karur by a French Mining Engineer, M. Chaper, of diamonds in a pegmatite rock in association with sapphires and rubies.

The "Blue rock."

What has attracted so much attention to Wajra Karur on the part of professed experts in diamond mining, M. Chaper excepted, has been the discovery there of a bluish tuff-like rock, which presents a strong superficial resemblance to some of the Kimberley "blue rock," that has

proved so marvellously rich in diamonds in the South African mines. My acquaintance with the South African diamond matrix is limited to one specimen of the Kimberley "blue rock" which I saw in our Museum in Calcutta in 1883. Very shortly after, on returning to Madras, I was shown specimens of the Wajra Karur "blue rock," and was so much struck by the great resemblance between the two that I immediately remarked on it to Mr. R. G. Orr (of Messrs. P. Orr and Sons), who had shown me the Wajra Karur specimens. The source of the South Indian diamonds seemed likely to be ascertained beyond a doubt, and one of the most interesting questions in South Indian geology on the eve of being answered.[1]

Whether the specimen of the Kimberley rock I examined was a good and typical one I cannot say, but it strongly resembled the Wajra Karur rock that I saw so soon afterwards. The latter, which is soft and crumbly, and full of cracks, lined with films of carbonate of lime, is from excessive weathering in such bad condition as to be quite unfit for microscopic examination. It is to be hoped that ere long much harder specimens, susceptible of grinding and polishing, will be procurable; for it is of the highest interest to ascertain whether this rock is also a variety of porphyritic peridotite, such as that forming the diamond matrix at Kimberley. The Kimberley matrix rock has been very fully described by the late Professor Carvill Lewis,[2] by whom it was regarded as a distinctly new rock type and appropriately named "Kimberlite."

The Wajra Karur neck.

The Wajra Karur "blue rock" occurs in a "neck" in the epidotic granitoid which forms the high ground north and west of the village. Owing to the immense quantity of quartzose débris, derived from the surrounding granitoid, which is scattered over the face of the country, the exact extent of the neck is not clearly seen, but it measures several acres in area.

Owing to its soft nature, the "blue rock" has weathered much quicker than the surrounding hard hornblendic gneiss, and has thus come to be worn into a hollow, which forms the head of the small stream flowing south-eastward through the village and falling into the Penner some 10 miles further on. The high road

[1] My first visit to Wajra Karur was after this, and the views I arrived at after a close examination of the diamond-yielding tract, were embodied in my paper "On the Geology of parts of the Bellary and Anantapur Districts," which appeared in the Records of the Geological Survey of India (Vol. XIX, pt. 2, 1886).

[2] In a paper read before the British Association at Manchester in 1887, an abstract of which was published in the Geological Magazine for March last. Unfortunately this does not give a full macroscopic description of the rock, by which to judge more fully of the external resemblances to the Wajra Karur rock.

P. S.—I have thought it better, in the interests of this enquiry, to append to this paper a reprint of Prof. Lewis' Note. The suggestion in it of *serpentine* in the form of a decomposed eruptive peridotite, as the original matrix of the diamond is of value in connection with the fact that the *Banaganpilli* group of the Karnul formation rests on, and is unconformable to, one group of the Kadapah formation which is largely made up of volcanic rocks, and some serpentine beds. We do not know of a centre or source from which these volcanic rocks may have risen; but at present there is nothing against such a source being related to the Wajra Karur "neck," or other volcanic vents which may eventually be recognized in the Bellary District.—W. K.

running south from Guntakal village and Timancherla Railway station passes across the eastern side of the neck, and the blue rock is to be seen here and there in the road-side ditches, while in a small road-metal pit close to the village it is seen in contact with the epidotic hornblende gneiss. As far as I have been able to ascertain the first explorer that noticed the "blue rock," was Mr. J. Brukowsky who visited Wajra Karur after seeing the Kimberley mines.

At the time of my two visits in November 1884 and January 1885, the neck was being largely and deeply prospected by Mr. A. Copley, a practical diamond miner of Kimberley experience, on behalf of Mr. R. G. Orr, of Madras, and others.

At the time of my final departure from Wajra Karur, Mr. Copley had either met with no success, or did not write and inform me of any subsequently, as he had promised me he would do. Such being the case and no tidings of the discovery of diamonds having reached me, I could but conclude that none had been found, either in the matrix, or by means of the very elaborate and perfect washing machinery largely used to test the nature of the local "blue rock." As diamonds are insoluble and resist weather action more successfully than any other mineral, the inference was obvious that no diamonds existed in the Wajra Karur rock so far as it had been tested, though the testing had been carried to considerable depths in several shafts and largely over the surface of the neck: furthermore no discoveries of diamonds were reported from the banks of the stream running down south-eastward to the Penner river nor from the deeply eroded lower ground through which it flows. It is manifest from the position of the neck that the great mass of material removed by denudation in forming the hollow in which it is seen exposed, must have been washed down the stream in question, and had diamonds occurred in that mass it is highly improbable that none should have been left in the bed and banks of the stream where their existence would certainly have been discovered by the old diamond seekers in former generations, who would have "shoaded" up the stream and have inevitably reached the neck.

Assumed absence of diamonds how accounted for.

My conclusion as to the absolutely negative results of Mr. Copley's research would appear to have been based on imperfect information, for a new company called the "Madras Presidency Diamond Fields Limited Company" was some months since started with the object of working what in their prospectus is set forth as a very promising field.

The remarks which I made on the subject of Mr. Copley's work in my paper "On the Geology of parts of Bellary and Anantapur Districts,"[1] were to the effect that he had been unsuccessful; and I ventured to put forth a hypothesis in explanation of the (supposed) absence of diamonds from a rock from which so much had been expected owing to its external resemblance to the Kimberley diamond matrix. My hypothesis was that the absence of diamond must be ascribed to the fact that the intrusive rock filling the neck had risen up through rocks containing no carbon in any form; which, as far as my knowledge of the surrounding epidotic hornblende gneiss extends is the essential character of that rock. The Kimberley peridotite on the contrary had passed through a great thickness of highly carbonaceous shales, the carbon derived from which (in whatever combination whether as CO

[1] Records, Geological Survey of India, Vol. XIX, part 2.

or CO_2) was occluded in the irruptive rock and gave rise to the innumerable crystals of pure carbon, as the heated mass cooled down. If this hypothesis be correct, the lower parts of the Kimberley and other peridotites in West Griqualand below the level at which the supply of carbon from the carbonaceous shales was obtainable should prove barren of diamonds; and it will be exceedingly interesting to watch the progress in depth of the diamond pits, as they should, in that case, in due time descend below the level at and above which diamonds were formed by the crystallising of the occluded carbon. If the Wajra Karur neck should on further examination prove barren in diamonds I shall consider my hypothesis as established.[1]

Hypothesis to explain the presence of diamonds at Wajra Karur.

Before I ever visited the Wajra Karur diamond field and only knew of it by report, I had often speculated (the existence of the neck of "blue rock" being then unknown) on the possible existence there, or in the neighbourhood, of outliers of the Kadapa or Karnul conglomerates from which, and especially from the latter, the diamonds might be derived by subaerial denudation: I therefore examined the country all around very closely, but failed to find any trace of a remnant *in situ* of the former extension over that region of members of either of those rocks series. That such extensions of those two series did once exist I cannot but firmly believe, although the tremendous denuding agencies that have been at work have left no visible traces *in situ* of the rocks in question. The only traces of those rocks now remaining are the few diamonds found scattered over the surface of that neighbourhood. They escaped the general destruction of the rocks they had been enclosed in owing to their intense hardness and durability and remained behind when every other trace of those rocks had vanished. A vastly greater number than those which were left was doubtless swept away with the general mass of débris and found its way either into the valley of the Penner, or from the more northern parts of the extensions into the valleys of the Tungabhadra and Kistna, and furnished in part the supply of diamonds obtained from the alluvial beds in the lower parts of those river valleys, but in far greater part were washed out into the Bay of Bengal, at the bottom of which diamond-bearing conglomerates have doubtless been formed. The mass of material removed in the destruction of the extensions I suppose to have formerly existed was doubtless vastly greater than what the whole existing alluvia of both river valleys now represent. When writing on Wajra Karur blue rock in my paper on the Bellary Anantapur country I was exceedingly loth to give up the idea that it was the source (or at least one great source) of the South Indian diamonds, but the entire absence of diamonds (as then supposed) from the rock then exposed in the neck was a difficulty I saw no way out of. Since then, however, while speculating on the subject, I have hit,

[1] The finding in the wash dirt of a limited number of small crystals and chips of diamond will not suffice to invalidate my hypothesis, as they might easily have been washed down from the surface through the innumerable cracks traversing so highly decomposed a material as the "blue rock." The finding, however, of a single crystal *in situ* in any undisturbed part of the "blue rock" would constitute it a true matrix and at once upset my hypothesis. As a matter of fact, I shall not at all regret having to relinquish my hypothesis, for then one source of the formation and occurrence of diamonds in India will have been established to the great gain of Geological Science.

upon what I think is a fair and legitimate solution of the problem, and it is this: when the "blue rock" was irrupted from below, that region was covered by a great thickness of sedimentary rocks, of which some were sufficiently carbonaceous in character[1] to furnish the carbon required to allow of the "blue rock" becoming charged on cooling with the carbon crystals, as was the case at Kimberley and in the other South African peridotite "necks." The "neck" rose to a great height above what now remains: in the course of time denuding agencies attacked the diamond-bearing portion of the neck of "blue rock," and the gems thus set free were washed away and imbedded in conglomerates, forming at a distance at lower levels from the materials of the neck and of the sedimentary rocks through which it had risen up. What was the age of the conglomerate of which the diamonds first formed part is a question that has yet to be worked out. The oldest conglomerate known to the Geological Survey in which diamonds actually occur is the basement conglomerate of the Karnul series, the Banaganpilli beds of Dr. King's excellent classification of that series. Old workings for diamonds were however carried on in apparently much older conglomerates belonging to the underlying Kadapa, and I met with one old set of workings[2] in the western part of the Bellary District which were in an unquestionable Dharwar conglomerate, which is of course of vastly greater antiquity. In the present state of our knowledge it is impossible to fix the age of the first conglomerate in which the diamonds of the Wajra Karur neck may have been included, for it is uncertain whether the old mines just referred to in the Dharwars and Kadapas really yielded diamonds or were only unsuccessful trial pits made, because of the petrological resemblance of the rocks they were made in to the unquestionably diamond-bearing pebbly conglomerates of the Karnul series.

How the "Blue rock" gained its carbon.

Age of oldest diamond conglomerate undetermined.

Old workings near Huvin Hadagalli.

The diamonds occurring in the Banaganpilli beds are just as much rolled pebbles as the jaspers, quartzites, quartzes, granites and gneisses, &c., which make up the Banaganpilli conglomerates. It is very difficult to obtain diamonds still imbedded in the conglomerate matrix, but I succeeded in procuring a couple of very small ones: unfortunately the fragment of matrix was much too small to make a decent hand

Banaganpilli diamonds true pebbles.

[1] The existence of such a series of carbonaceous rocks may be very reasonably postulated, though singularly enough none of the sedimentary rocks whose extensions may be supposed to have been penetrated by the "blue rock" neck and thus to have furnished the carbon requisite show any traces of carbon in their remaining areas.

[2] This old working which presented all the features characteristic of a diamond working occurs on a small hill of pebble conglomerate about 3 miles south of Huvin Hadagalli in the western part of Bellary District. The conglomerate forms part of the Dambal-Chicknâyakanhalli band of the Dharwar rocks. The surface of the hill is riddled with a number of little pits identical in appearance with those frequently seen in the Karnul diamond district. Between the pits were here and there little platforms of earth with stone revetments, exactly like the sorting tables seen at the Banaganpilli diamond mines. I could see no trace of any other mineral in quest of which these little pits could have been made, and the peculiarity of the conglomerate immediately suggested their having been diamond pits. The civil authorities at Huvin Hadagalli were ignorant of their existence, and I have been unable to find out anything about them by subsequent enquiries.

specimen, though large enough to show what local rock the gems occurred in. One of the two diamonds was a mere broken fragment when imbedded.

Only one neck known at present.

The Wajra Karur neck is the only one as yet known in South India, but it is not unlikely that others of similar character may be found in other parts. It is difficult to understand the wide distribution of diamonds over the peninsula, if they were all derived from a single centre, but if other necks existed to the north, or north-east especially, this difficulty would entirely vanish. It is quite probable that the remains of such other necks may occur in the wide spreads of granitic and gneissic rocks—lying between the Kadapa and Karnul basins on the east and the Kaládgi and Bhima basins to the north-west. None were met with in such parts of the granitic area as were examined by the Geological Survey, but a great part of that area remains unsurveyed, while much of the surveyed tracts could not be gone over exhaustively. Should the Wajra Karur neck turn out productive of diamonds, the whole of that tract should be closely prospected, for a neck might well exist without any traces showing of a kind to have attracted the attention of native prospectors, for they had certainly not recognized the Wajra Karur neck as a source of diamonds. The prospecting will have to be carried out by a process of most minute "shoading," especially where the cotton soil spreads occur. Even with the most searching process of shoading it will be impossible to effect an exhaustive examination of much of the country, for there are tracts measuring many thousands of acres in extent where no streams cut through the cotton soil, and the sub-rock not being exposed no "shoad stones" can be seen to guide the prospector.

M. Chaper's paper.

It is only lately that I became aware of the existence in the Bulletin de la Société Géologique de France, for 1886, of a paper by M. Chaper, a French mining engineer, on "A diamondiferous pegmatite in Hindustan."[1]

The only notice of this, if true, very remarkable discovery I had seen was a very brief paragraph in (if I remember rightly) the "Madras Mail," making the barest mention of it and without any particulars as to the locality, or circumstances, of the find. Mr. Chaper's paper, from which I give some extracts further on, is unfortunately unaccompanied by any map or plan showing the exact locality of his find, and the written account of it is so vague that I do not think it would be possible to determine the spot even if on the ground. This is very much to be regretted as it prevents his discovery being put to a crucial test by tracing out the pegmatite vein whence he derived his diamonds, sapphires, and rubies. Could this be done, the validity of his claim could speedily be decided by mining the vein in question. If his gems really came out of the vein, it is most unlikely that others would not be found in it, and it would be possible, and probably easy, to determine to which of the many series of veins traversing the older crystalline rocks of that region that particular vein belonged.

According to his own showing however, he regarded his results as most unfavourable from a practical point of view, and as holding out but very poor hopes of the pegmatite proving a remunerative source of diamonds. His arguments for believing

[1] "Note sur une Pegmatite diamondifère de l'Hindustan."

the pegmatite to be the matrix in which carbon crystallised into diamonds will be examined further on. I will merely state here that to my mind his views are quite mistaken, and that he utterly fails in substantiating his supposed discovery. Such being the case, I shall give but a brief review of his lengthy paper, for, although I took the trouble of translating nearly the whole of it, it is not worth reproducing in print.

From his description of the place I cannot identify it with any I visited, and it lies far to the east of the most easterly place pointed out to me as having yielded diamonds on the surface. Had his description been less vague and imperfect, I should have made a point of returning to the place and hunting it up. Unfortunately I never heard the whereabouts of his work till long after I had finished mine around Wajra Karur.

He begins his paper by long notes about the country at and around Bellary town, perfectly irrelevant to the matter in hand. Eventually he gets to Wajra Karur and begins to examine the country round about. He recognised correctly the change in the characters of the country on either side of the divide between the drainage basins of the Tungabhadra and the Penner, but failed to recognize the presence of the neck and the blue rock in it. Unless the high road then existing ran differently from what the road does now, he must have actually travelled across the east side of the neck and have overlooked the blue rock exposed in the road side ditches. He must also have examined that side of the village very superficially; presumably he let himself be influenced by the accounts given by the natives of the different localities where diamonds of note had of late years been collected.

Did not find the blue rock.

Of the many spots pointed out to me as having yielded notable diamonds within late years, none lay in the hollow occupied by the neck, but all on the surrounding higher grounds to the north-north-east and east, all of which consist of epidotic granitoid. Several were in the fields some distance eastward of the village. According to his own showing M. Chaper devoted himself mainly to the exploration of the tract east of Wajra Karur, as will be seen further on—

"It was therefore to the eastward of Wajra Karur that my reseaches had to be directed with the object of establishing the wealth in diamonds of this tract.

"It has in fact produced them from time immemorial; this fact appears to me established beyond a doubt by all the evidences that I collected. Numerous depressions which are still to be seen to-day around Wajra Karur may have originated from ancient workings, anterior probably to the English domination. But since a very long time all work of this kind has ceased. The statements of the people are quite in agreement with this; it is from the surface of the country that the diamonds are collected now-a-days. After storms people of the lowest class (chucklers) wander about over the fields in rocky and uncultivated places; the more rainy the season has been and the more violent the storms have been the better their chances of remunerative finds. The best are but very modest according to the witnesses I heard, and would be far from remunerative if the time devoted to them were not in other respects of no value to the searchers."

M. Chaper was wrong in this, as some of the stones found thus on the surface have been of considerable value. Amongst them, though not at Wajra Karur itself but at some distance to the north-west (if I was rightly informed), was the "Gor-do-Norr" valued at from 10,000 to 15,000 pounds.

He accordingly gets to work at Wajra Karur and examines especially the tract eastward of the village, and after a time concludes that "in all the neighbourhood of Wadjra Karur there are no traces of transported matter.[1] The surface of the ground is entirely composed of the products of disaggregation and decomposition of the underlying rock."

This point he insists upon strongly, as it supports his contention that the gems he found (apparently) in the soil at foot of some rock containing pegmatite veins could only have been derived from the decomposition of some vein in closest proximity; they could not have been brought thither from any distance.[2] The rock is cut up in every direction by small veins of injection which weather more slowly than the general mass and thus stand out in a conspicuous network—

"In the divisions of this network all the elements dissociated from the rock are in a condition of juxtaposition excepting those of the surface, which the foot of an animal or the root of a plant have been able to disturb."

Four principal rocks east of Wajra Karur.

M. Chaper observed four principal rocks in the course of his study of the tract east of Wajra Karur, and says: "The predominant rock is an amphibolic rock," and then proceeds into a petrological disquisition why it should not be regarded as a "hornblendic gneiss," the definition given to it by M. Fouqué, the French petrologist, who examined M. Chaper's specimens microscopically. The rock forming the country to the east of Wajra Karur is most distinctly and typically a hornblendic gneiss, though most extraordinarily cut up by small veins of several ages to such an extent in many places as to mask the true lamination of the gneiss.

Hornblendic diorite.

M. Chaper prefers to call it a "hornblendic diorite," a name which is probably quite applicable to a certain boss of hornblendic rock, varying considerably in its character within narrow limits, which rises some 5 or 6 kilometres to the east-south-east of Wajra Karur.

Pegmatite.

The next rock in importance is a pegmatite, according to both his own and M. Fouqué's determination. It consists of orthose or microcline of a bright salmon pink, pale oligoclase, limpid quartz, and epidote; the latter forming a network of strings and veinlets of all sizes, and being an original constituent of the rock, not a subsequent product of infiltration. Its colour makes it a conspicuous rock.

Metamorphic felspathic grit.

The third rock "of probably metamorphic sedimentary origin," which appears only to have been seen in occasional fragments in his excavations, he regards as a "Metamorphic felspathic grit."

Granulite.

The fourth rock, a grey or blackish grey, fine grained granitoid, consisting of orthose, white and white and black micas and quartz, M. Fouqué terms a *granulite*, a definition which M. Chaper adopts.

[1] This is a very near approach to the truth. After several days close searching I could only find a couple of true water-worn brown quartz pebbles, specimens of not the least earthly use as indications of the age of the formation they were derived from. These and, according to my hypothesis, the diamonds themselves here occurring, are the only survivals of the first or second conglomerate which I suppose to have been denuded away bodily.

[2] This is rather a hazardous contention in view of the torrential character of occasional rainstorms in those regions.

Their ages.

He arranges the four rocks according to their age as follows:—"Granulite, hornblendic diorite, epidotic pegmatite, metamorphic felspathic grit," the first being the oldest. He does not, however, make their relations to each other at all clear, but leaves one to infer them. It does not appear whether the pegmatite occurs in bosses, or veins, or what; merely that it is met with near the hornblendic boss referred to before, though the fact of its being a later arrival is established. It is, therefore, presumably an intrusive rock, but not necessarily of very vast antiquity, for it occurs largely in the Dharwar system, both in veins and in lenticular masses.

The injection veins.

According to M. Chaper the injection veins which form such a wonderful network in the hornblendic gneiss (diorite *selon lui*) are referable to two types—a granulitic and an andesitic with augitic porphyrite; the former being subdivisible into a purely granulitic, an epidotic granulitic, and a syenitic (granulitic?)

He next refers "to the single mineral vein," which exists 7 or 8 kilometres south of Wajra Karur and describes it. It is nothing more than a great run of exceptionally white brecciated fault rock, consisting of nearly pure quartz, which forms a considerable rocky ridge known as the Tellakonda (hill).

He then proceeds as follows:—

Connection between the diamonds and different soils.

"It is certainly superfluous to say that the places where the natives find and collect the diamonds are not situated indifferently on one or other of the above-named rocks. In this matter they have the teachings of an experience not very enlightened, it is true, but of great antiquity, which admits little room for error. Finally, one may recapitulate their ideas on this subject by saying that the soils which they consider the most productive are those derived from the weathering *in situ* of the coarse grained rocks in which the salmon coloured orthose predominates and of the metamorphic rocks. The granite and the hornblendic diorite would then, according to them, be sterile. I could devote but little time to the verifying of these latter purely negative indications. I had, above all things, to go to the point as directly as possible, that is to say, to verify the existence of diamond where it was alleged to occur.[1] For this purpose I had many excavations made at places situated most diversely with reference to the underlying rocks, but preferably on the first. M. deMorgan, who was my associate in this expedition, and I watched the extraction and washing of the materials derived from these excavations, and we performed the picking over, the produce being two diamonds, two sapphires and three rubies. We are both of us convinced that these gems came quite authentically from the excavated material, and had not been introduced by fraud. All were found at the very moment of being turned out, and during the using of pick and shovel. The fastidious and weary labour of washing and picking over resulted in nothing."

The finding of the gems.

This is all the evidence offered by M. Chaper, and he then proceeds to recapitulate the results, on which he remarks:—

But not *in situ*.

"The interest of the results would have been singularly increased could I have brought back with me diamond and corundum in their gangue. I regret more than any one can not having been able to produce and submit to all comers such a material fact, which would prevent all doubt and discussion."

His arguments in favour of the occurrence of diamonds in pegmatite will, I think, convince very few people. He met with great incredulity on the part of the people in Madras, who were interested in his exploration, where he was believed to have been tricked. Nobody else seems ever to have found rough sapphires and rubies, or indeed corundum in any shape near Wajra Karur, and several experts considered that one of his rubies showed signs of cutting!

Was he tricked?

There was evidently no attempt to "salt" the ground to make it attractive in order to have it favourably reported on, but it is very likely that the few little stones that were found might have been introduced despite his careful watching by some one interested in making him continue his exploration.

His results were certainly very discouraging to his principals, for they were as poor as poor could well be. To my mind it is surprising that with such exceedingly slender theories only, instead of facts, he should have ventured to write a paper and lay it before such a highly scientific body as the Société Géologique de France.

APPENDED NOTE.

"*The matrix of the Diamond.*[1] *By* PROFESSOR H. CARVILL LEWIS.

A microscopical study of the remarkable porphyritic peridotite which contains the diamonds in South Africa demonstrates several interesting and peculiar features.

The *olivine*, forming much the most abundant constituent, is in porphyritic crystals, sometimes well bounded by crystal faces, at other times rounded and with corrosive cavities, such as occur in it in basaltic rocks. It rarely encloses rounded grains of glassy bronzite, as has been observed in meteorites. The olivine alters either into serpentine in the ordinary way, or into an aggregate of acicular tremolite crystals, the so called '*pilit*,' or becomes surrounded by a zone of indigo blue bastite—a new variety of that substance. The olivine is distinguished by an unusually good cleavage in two directions.

Bronzite, *chrome diallage*, and *smaragdite* occur in fine green plates, closely resembling one another. The bronzite is often surrounded by a remarkable zone, with a centric, pegmatitic, or chondritic structure, such as occurs in certain meteorites. This zone is mainly composed of wormlike olivine grains, but a mineral having the optical characters of cyanite also occurs in this zone.

Biotite, a characteristic constituent, occurs in conspicuous plates, often twinned, generally rounded, and distinguished by its weak pleochrism, a character peculiar to the biotite of ultrabasic eruptive rocks. It alters by decomposition into the so-called *Vaalite*.

Perovskite occurs in very numerous but small crystals, which optically appear to be compound rhombic twins.

Pyrope is abundant in rounded red grains. Titanic iron, chromic iron, and some fifteen other minerals were also found. Rutile is formed as a secondary mineral through the alteration of the olivine into serpentine, being a genesis of rutile not heretofore observed.

The *chemical composition* shows this to be one of the most basic rocks known, and is a composition which by calculation would belong to a rock composed of equal parts of olivine and serpentine, impregnated by calcite.

The *structure* is at the same time porphyritic and brecciated, being one characteristic of a volcanic rock which after becoming hard had been subjected to mechanical movements. It is a volcanic breccia, but not an ash or tuff, the peculiar structure being apparently due to successive paroxysmal eruptions. A similar structure is known in *meteorites*, with which bodies

[1] Report, Brit. Assoc. for the Advancement of Science, 1887, Manchester; p. 720.

this rock has several analogies. A large amount of the adjoining bituminous shale is enclosed, and has been more or less baked and altered. The occurrence of minute tourmalines is evidence of fumarole action.

The microscopical examination supports the geological data in testifying to the igneous and eruptive character of the peridotite, which lies in the neck or vent of an old volcano.

While belonging to the family of peridotites, this rock is quite distinct in structure and composition from any member of that group heretofore named. It is more basic than the picrite-porphyrites; and is not holocrystalline-like dunite or saxonite. It is clearly a new rock-type, worthy of a distinctive name. The name *Kimberlite*, from the famous locality where it was first observed, is therefore proposed.

Kimberlite probably occurs in several places in Europe, certain garnetiferous serpentines belonging here. It is already known at two places in the United States: at Elliott County, Kentucky, and at Syraçuse, New York; at both of which places it is eruptive and post-carboniferous, similar in structure and composition to the Kimberley rock.

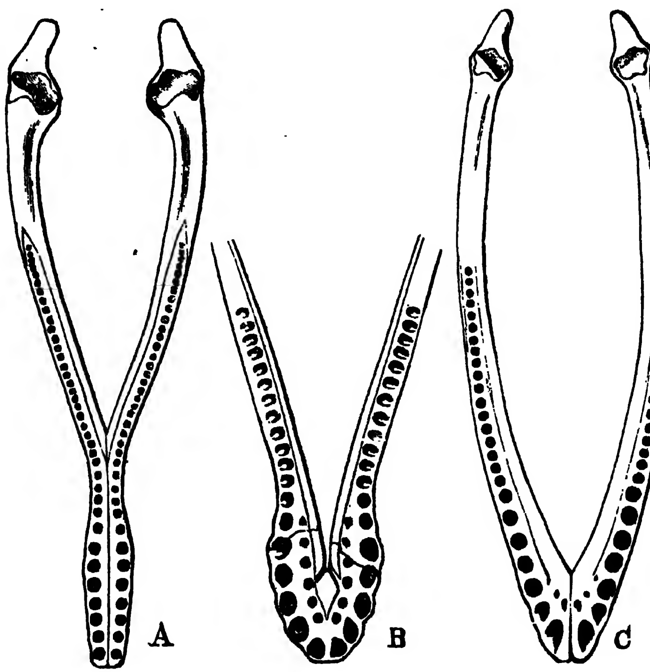
At the diamond localities in other parts of the world diamonds are found either in diluvial gravels or in conglomerates of secondary origin, and the original matrix is difficult to discover. Thus, in India and Brazil the diamonds lie in a conglomerate with other pebbles, and their matrix has not been discovered. Recent observations in Brazil have proved that it is a mistake to suppose that diamonds occur in itacolumite, specimens supposed to show this association being artificially manufactured. But at other diamond localities, where the geology of the region is better known than in India or Brazil, the matrix of the diamond may be inferred with some degree of certainty. Thus, in Borneo, diamonds and platinum occur only in those rivers which drain a serpentine district, and on Tanah Laut they also lie in serpentine. In New South Wales, near each locality where diamonds occur, serpentine also occurs, and is sometimes in contact with carboniferous shales. Platinum, also derived from eruptive, occurs here with the diamonds. In the Urals, diamonds have been reported from four widely separated localities, and at each of these, as shown on Murchison's map, serpentine occurs. At one of the localities the serpentine has been shown to be an altered peridotite. A diamond has been found in Bohemia in a sand containing pyropes, and these pyropes, are now known to have been derived from a serpentine altered from a peridotite. In North Carolina a number of diamonds and some platinum have been found in river sands, and that State is distinguished from all others in Eastern America by its great beds of peridotite and its abundant serpentine. Finally, in Northern California, where diamonds occur plentifully and are associated with platinum, there are great outbursts of post-carboniferous eruptive serpentine, the serpentine being more abundant than elsewhere in North America. At all the localities mentioned chromic and titanic iron ore occur in the diamond-bearing sand, and both of these minerals are characteristic constituents of serpentine.

All the facts thus far collected indicate *serpentine*, in the form of a decomposed eruptive peridotite, as the original matrix of the diamond.'

On the Generic Position *of the so-called* Plesiosaurus indicus, *by* R. LYDEKKER, B.A., F.G.S.

In describing the symphysis of a Sauropterygian mandible from the Umia stage of the Gondwánas of Kach in the 'Palæontologia Indica' (Ser. iv, pt. 3, p. 28, pl. vi, fig. 1), to which I applied the name of *Plesiosaurus indicus*, I remarked upon its apparent close resemblance to the imperfect mandible of a Sauropterygian from the English Lower Lias figured in Buckland's 'Geology and Mineralogy' (Bridgewater Treatise), pl. ix, fig. 3. I was, however, at that time, owing to the want of literature,

unaware that the English specimen had been made one of the types of *Plesiosaurus arcuatus*, Owen. Thanks to the Director of the Survey, I have recently been able to make an actual comparison of these two specimens, the result of which not only justifies my previous comparison, but also shows that the differences I have pointed out are merely due to the English specimen having been somewhat flattened by pressure. So far, indeed, as I can see, there is not even any specific distinction between the two specimens; but as the wide difference in their geological horizons (the Umia stage being correlated with the Upper jurassic) probably indicates that the two forms are specifically different, I propose to retain my specific name for the Indian one. In *B* of the accompanying woodcut the Kach specimen is figured, with



Three types of Sauropterygian mandibles. *A. Peloneustus philarchus*; from the Oxford Clay of Northamptonshire, ⅛. *B. Thaumatosaurus indicus*; from the Umia stage of Kach, ⅐. *C. Plesiosaurus dolichodeirus*; from the Lower Lias of Somersetshire, ⅖.

a restoration of the missing part of the dentary from the English example. And it will be seen from this figure that the mandible is characterised by its spoon-shaped symphysis, which is of considerable length, and has five dental alveoli of much larger size than those of the rami. The posterior border of the oral surface of the symphysis is also marked by a diamond-shaped prominence.

The other specimens drawn in the accompanying woodcut are intended to show the difference of this type of mandible from those of other Sauropterygians. The mandible on the right hand of the figure (*C*) is that of *Plesiosaurus dolichodeirus*—

the type of the genus—from the Lower Lias; while the one on the left (*A*) is that of a Sauropterygian from the Oxford Clay to which, in a paper recently communicated to the Geological Society, I have applied the generic name of *Peloneustus*. The former, it will be observed, has a short V-shaped symphysis, without any marked enlargement of the anterior teeth; while in the latter the symphysis has become extremely elongated and narrow.

In the paper above-mentioned I have brought forward evidence to show that the so-called *Plesiosaurus arcuatus*, together with the allied *P. megacephalus* of the same beds, and *P. cramptoni*, of the Upper Lias, should be referred to the genus *Thaumatosaurus*, originally described upon the evidence of vertebræ and teeth from the Great Oolite of Würtemberg. The species of that genus, in addition to certain peculiar features of the pectoral girdle, are characterized by their relatively large skulls, having a spoon-shaped mandibular symphysis, and large anterior teeth; by the neck being relatively short and thick; and by the cervical vertebræ having very short centra, with nearly circular and deeply cupped terminal faces, and double costal facets. To this genus must also be referred the Kach Sauropterygian, under the name of *Thaumatosaurus indicus*.

This genus appears to have its last English representative in the Kimmeridge clay, — the approximate equivalent of the Umia stage,—but that species seems to have been of very rare occurrence. Some signs of affinity with *Peloneustus* are shown by *Thaumatosaurus;* but the former is readily distinguished by the characters of the pectoral girdle, by the extremely long mandibular symphysis, and the ellipsoidal contour and slight cupping of the terminal faces of the cervical vertebræ, while in many of its characters it makes a marked approach to *Pliosaurus*.

On Flexible sandstone *or* Itacolumite, *with special reference to its nature and mode of occurrence in India, and the* cause of its Flexibility: *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With 2 plates.)

The existence of a peculiar flexible form of rock, afterwards called Itacolumite, appears to have been known as far back as 1780 when specimens were brought from Brazil by the Marquis de Lavradio, Viceroy at Rio de Janeiro. But, though known to science for more than a century, it appears never to have attracted much attention, and, to this day the descriptions in textbooks are, for the most part meagre and inaccurate. Not infrequently it is said to be the original matrix of the diamond, and with only one exception, so far as I am aware, the flexibility is always said to be due to the presence of mica.

The first of these myths appears to have been the outcome of a survival of mysticism and to a belief, no weaker for being unexpressed, that so valuable and rare a gem as the diamond could not be of common origin: and, when in the same district that yielded diamonds there was found a peculiar and mysterious rock in

which the diamond appears to have been occasionally observed, this was enough to give rise to the belief in an intimate and necessary connection between the two. But a similar rock has since been found in other parts of the world unaccompanied by diamonds, nor does there seem to be any reason for supposing that in Brazil the diamonds are other than of derivative origin and that their association with itacolumite is other than accidental.

The second statement, that mica is the cause of its flexibility, can be traced to the authority of Von Eschwege,[1] who is also responsible for the fancy name of Itacolumite. But the fact that mica seldom, if ever, forms a large proportion of the rock, and is in some cases entirely absent suffices to prove that the flexibility is, in some cases at least, not due to the presence of this mineral.

Besides the usually small proportion, and occasional absence, of mica in the rock, the nature of the flexibility it possesses is very different from that of mica or any of the other flexible minerals. If one of the flexible specimens be examined it will be found to yield with the greatest readiness to any force applied, and can be stretched, compressed, or bent in any direction with the greatest ease, up to a certain limit at which, to use a slang but expressive term, it "jams", and no further application of force will cause it to yield except by actual fracture. The extent to which some of the softer specimens will bend, when cut into thin slabs, is remarkable; one specimen, 17 inches long and three quarters of an inch thick, allowed its end to be lifted 7 inches vertically from the table on which it lay before the other end moved. This great degree of flexibility is only shown by very soft and decomposed specimens, and there is every gradation from them to hard pieces whose flexibility is only noticeable when cut into thin slices, but in every case the flexibility is the same in kind and differs only in degree.

Another fact, which does not lend any support to the mica theory, is that the flexibility is invariably exhibited by decomposed specimens only. At Kaliána[2] the flexible stone occurs on a hill composed of vertically bedded glassy quartzites; it is confined, so far as my investigations and enquiries went, to one single spot where, for about 20 feet across the strike and for about 30 yards along it, the rock has become flexible; near the margin of this area the flexible stone passes downwards into the ordinary quartzites, but in the centre the decomposition had extended downwards to the floor of the quarry, a depth of fully 15 feet; here, too, the rock was much softer, more decomposed, and flexible than nearer the margin.

The same connection between decomposition and flexibility has been noticed in Brazil by Von Eschwege, who says that the more decomposed and iron-stained the rock becomes, the more flexible it is. He also notices that the stone yielded by one and the same bed is flexible at one place, at another not, and that the peculiarity is not confined to one particular bed, but may be found affecting several distinct, superimposed beds. Mr. Tuomey in his report on the geology of S. Carolina notices that the Itacolumite of that State "passes even in the same mass into compact quartz, to be distinguished from common quartz only by its stratified structure," and at another place that "the passage from the arenaceous to the compact variety is gradual, and it is in this passage that it assumes the form of *itacolumite*." The same

[1] *Poggendorf, Annalen* LVII, 100, (1817); LIX, 136; (1818).
[2] 4 miles from Dádri in Jhind.

observations are conspicuously applicable to Kaliána, and I attribute the fact that flexible stone has only been recorded from one locality, to the extent to which this hill has been riddled with quarries that have been worked for centuries to supply building and quern stones, while elsewhere the same rocks are, as a rule, almost untouched. Did these rocks contain mineral wealth that would encourage prospecting it is probable that other localities for flexible stone would be discovered.

From these considerations we may conclude that the flexibility of the rock is due, not to the flexibility of any of its constituents, but to some peculiarity in the mode of aggregation of the individual grains of quartz and other material of which it is composed. This conclusion is not now enunciated for the first time, for I find that, in 1785, the Chemist, M. H. Klaproth, published a description of the "Flexible quartz of Brazil," in which the following passage occurs: "I am inclined to think that the elasticity of this fossil originates solely from the form of its aggregation; for, as may be distinctly seen at the first glance in the entire stone, all those longish lamellæ are interwoven in one single direction, and implicated in such manner that each junction resembles a vertebra or hinge. With this idea also corresponds the particular kind of the flexibility of the stone, which is not tough or coriaceous."[1] This, though not a complete explanation, is far more correct and satisfactory than that which has been repeated in all manuals and text-books, with the exception of that by Prof. S. Haughton, who says "occasionally, in some rare cases—which, as far as I have any knowledge of them, are confined to Brazil, South Carolina and Delhi—you have a rock composed of particles of sandstone which are not in contact with each other but lie in a paste of felspathic clay, which paste permits a certain amount of motion between the particles of the mass." An explanation which is incomplete only in so far as it does not explain how a rock so constituted could hold together.

It now remains to determine the nature and origin of the structural peculiarity to which the rock owes its remarkable character.

If a slice of flexible stone is examined under the microscope, by reflected light, it exhibits a structure most conspicuous in all the specimens of flexible, and equally conspicuous by its absence from all specimens of non-flexible, stone I have examined. The rock consists of irregular aggregates of grains of quartz separated from each other by fissures and crevices which extend deep into the stone and give one the impression of ramifying through its mass further than they can be actually traced. Should one of these aggregates of quartz grains be touched with a needle it will be found loose and easily moveable from side to side, but it cannot be displaced without fracture, either of itself, or of the surrounding particles. In fact, the rock consists of a number of irregular aggregates of quartz which hold together by projections on one fitting into hollows in another, while the clear space between them allows of a certain amount of play.[2] I have attempted to portray this structure in fig. 1, but it is extremely difficult to represent in any mere delineation, which does not allow of a demonstration of the mobility of the individual aggregates.

The descriptions of Von Eschwege exhibit the Brazilian stone as belonging to a

[1] *Schrift. Berl. Ges. Naturf. Freunde.* VI, 322, (1785). The original not being accessible, I have quoted from "Analytical essays towards promoting the Chemical Knowledge of Mineral Substances by Martin Henry Klaproth." 8°. London (1801), p. 410.

[2] Since writing the above I have met with a short paper by O. Mügge in which the same view of the flexibility of the stone is declared.—*Neu. Jahrb.*, I Band, 1887, pp. 195-197.

highly metamorphosed formation, and even the decomposed flexible specimens from the Brazils and Georgia show some signs of the metamorphism they have undergone. They are both much more finely laminated than the Kaliána stone and the surfaces of the laminæ, along which the rock splits with ease, are covered with fine plates of silvery mica, which are all drawn out in one direction. The presence of this mica doubtless gave rise to the idea that it was the cause of the flexibility of the stone, but in those specimens accessible to me they are not confluent and form but a very small proportion of the stone. Their arrangement with the longer axis of each pointing in the same direction can hardly be due to their original deposition in this manner; it seems more probable that the rock has been subjected to great pressure and at the same time to the softening influence of heat and superheated water, and, under the influence of these, has been squeezed or drawn out in the direction marked by the lengthening of the plates of mica. Possibly, too, what has been described as lamination may in fact be an imperfect cleavage structure.

However this may be, there can be no doubt that the quartzites of the Kaliána hill have been subjected to intense metamorphism. Under the microscope the individual quartz grains are seen to be compressed together and to interlock with each other in the most elaborate manner. The general indications of metamorphism and even incipient fusion have been sufficiently described by Colonel McMahon [1], and it is unnecessary to dwell further on them here.

In the Kaliána rock there is, besides the quartz and accessory minerals, a certain proportion of felspathic paste, more conspicuous in sections cut transverse than in those cut parallel to the bedding. This paste does not surround the individual grains of quartz, but occupies spaces between aggregates of several grains, and it is to the decomposition and removal of this paste that the flexibility of some decomposed specimens is due. In such a rock the development of a flexible structure depends on the proportion and mode of distribution of the felspathic mud; if absent or only present in a very small proportion, decomposition will not extend deep into the rock, the quartz grains will be detached and fall off, leaving the undecomposed rock with a mere film of weathered stuff on the surface: if it is too evenly distributed, the quartz grains will not be in sufficiently intimate contact with each other, and as the rock weathers it will decompose into grains of sand easily detached and removed: if finally it should be suitably distributed, but too large in amount, the voids left by its removal will be so large that the quartz aggregates will not interlock with each other. The number of conditions that must be fulfilled accounts satisfactorily for the rarity of flexible sandstone and to a certain extent for the capriciousness of its distribution in rocks which are of the same age and have to all appearance the same composition and structure.

The only method of proving the hypothesis maintained above, would be the discovery of a flexible rock in which a similar structure was due to a different cause, and such evidence is fortunately provided by the discovery, by the late Mr. F. Fedden of a flexible sandstone near Chárli [2] south of the Pemganga river in Berar. It is an ordinary soft sandstone of rounded grains of quartz, with a little felspar, held together by a cement of carbonate of lime, which forms 35·9 per cent. of the whole

[1] Rec. Geol. Sur., Ind., XVII, 101—18, (1884).

[2] *Vide* Mem. Geol. Surv., Ind., XIII, 16, (1877).

mass. Here there is no comparatively soluble material whose removal leaves the rest of the rock as a mass of irregular aggregates interlocking with each other, for on removal of the cement, by solution, the rock falls into sand. But if the fractured surface of the rock is examined an abundance of sheeny patches point to a crystallisation of the cementing matrix, and these crystals offer a number of planes in various directions along which solution proceeds with greater rapidity than elsewhere, and as a result the rock becomes divided into irregular interlocking aggregates of sand and calcite.

We have then two distinct rocks of vastly different ages, the Chárli rock being Permian or upper Carboniferous at the oldest, while the Kaliána rock is certainly at the newest lower palæozoic; one exhibiting a high degree of metamorphism, the other showing no traces of it, one highly disturbed, contorted and compressed, the other lying almost flat and undisturbed, one almost pure quartz, the other containing a large proportion of carbonate of lime, agreeing only in two points, that both occasionally decompose into a mass of irregular interlocking aggregates, separated by empty spaces, and that where this has taken place, both exhibit a peculiar and remarkable flexibility of precisely similar character. It is impossible to avoid the conclusion that there must be an intimate relation between these two peculiarities and that the flexibility is the direct result of the unusual structure of the rock.

We have then an hypothesis which allows of the observed fact that thin slabs can be bent further than thick ones; for the same absolute lengthening or shortening of the opposite surfaces will result in a greater angular displacement when they are close together than when far apart. It accounts for the rock being always a product of decomposition; for the structure postulated could not be innate, and could only arise from the partial removal of a once solid rock. And, lastly, it is in perfect accordance with the peculiar nature of the flexibility of the rock.

Flexible sandstone is accordingly a rock in which incipient decomposition has resulted in its division into a number of irregularly-shaped aggregates, whose irregularities interlock and hold them together, while the intervening free spaces allow them individually a certain freedom of movement, and to the rock as a whole a certain degree of flexibility within limits governed by the size of the individual aggregates and of the free spaces between them.

Note.—It may not be uninteresting to record here the localities where flexible stone occurs.

In America besides Mexico there are the localities in North and South Georgia and South Carolina. In Europe it is said to have been found in the Rhine valley, (*Neu. Jahrb.* 1841, p. 566), in Galicia it occurs *bien caractérisé* (*Bull. Soc. Géol. France,* 1834, p. 416) and it is said to be found in the Ural mountains (*Zeits. Deut. Geol. Ges.* 1849, p. 484), but the term here appears to be used as synonymous with a micaceous quartzite containing diamonds; at p. 487 Baron von Humboldt quotes Jacquemont as an authority for the occurrence of Itacolumite in India, but he refers to the diamond bearing Vindhyan sandstones of Panna, and not to the flexible stone referred to above, with which Jacquemont does not seem to have been acquainted.

In Asia I know of none but the two localities mentioned in this paper.

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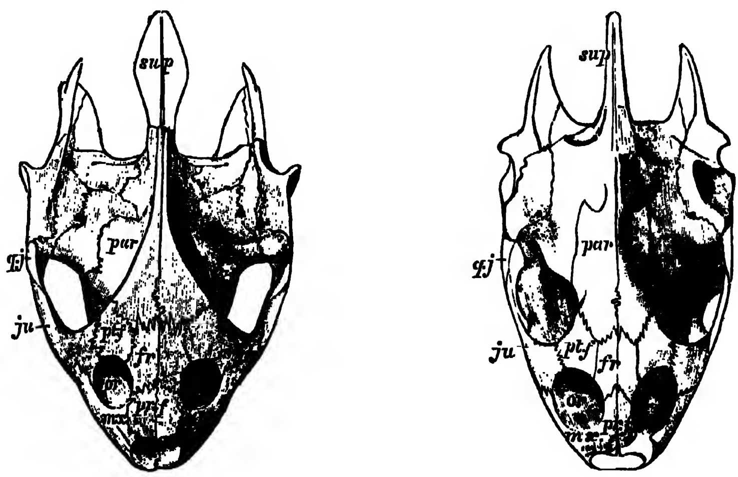
Notes on Siwalik *and* Narbada Chelonia, *by* R. LYDEKKER, *B.A.*, *F.G.S.*, *&c.*

Since it is always desirable in describing fossil Chelonia to have the evidence of the skull as well as that of the shell, I am glad to take the opportunity of figuring the skull of an *Emyda* from the Siwaliks of Perim Island acquired a few years ago by the British Museum, since we have hitherto known this genus in a fossil state solely by the shell. In order to exhibit the points in which the skull of *Emyda* differs from that of *Trionyx*, I have figured side by side with that of the former genus, a cranium of *Trionyx gangeticus* from the Pleistocene of the Narbada valley—



A. B.

Frontal aspect of the skulls of (A). *Emyda (cf.) granosa*, and (*B*) *Trionyx gangeticus*; restored and reduced to the same scale. *Sup.* supraoccipital; *par.* parietal; *pt.f.* post frontal; *fr.* frontal; *pr.f.* prefrontal; *mx.* maxilla; *ju.* jugal; *q.j.* quadrato-jugal; *or.* orbit.

NOTE.

It is requested that the accompanying pages may be substituted for pages 55 and 56 in Part I, Vol. XXII, of the "Records of the Geological Survey of India."

mass. Here there is no comparatively soluble material whose removal leaves the rest of the rock as a mass of irregular aggregates interlocking with each other, for on removal of the cement, by solution, the rock falls into sand. But if the fractured surface of the rock is examined, an abundance of sheeny patches point to a crystallisation of the cementing matrix, and these crystals offer a number of planes in various directions along which solution proceeds with greater rapidity than elsewhere, and as a result the rock becomes divided into irregular interlocking aggregates of sand and calcite.

We have then two distinct rocks of vastly different ages, the Chárli rock being Permian or upper Carboniferous at the oldest, while the Kaliána rock is certainly at the newest lower palæozoic; one exhibiting a high degree of metamorphism, the other showing no traces of it, one highly disturbed, contorted and compressed, the other lying almost flat and undisturbed, one almost pure quartz, the other containing a large proportion of carbonate of lime, agreeing only in two points, that both occasionally decompose into a mass of irregular interlocking aggregates, separated by empty spaces, and that where this has taken place, both exhibit a peculiar and remarkable flexibility of precisely similar character. It is impossible to avoid the conclusion that there must be an intimate relation between these two peculiarities, and that the flexibility is the direct result of the unusual structure of the rock.

We have then an hypothesis which allows of the observed fact that thin slabs can be bent further than thick ones; for the same absolute lengthening or shortening of the opposite surfaces will result in a greater angular displacement when they are close together than when far apart. It accounts for the rock being always a product of decomposition; for the structure postulated could not be innate, and could only arise from the partial removal of a once solid rock. And, lastly, it is in perfect accordance with the peculiar nature of the flexibility of the rock.

Flexible sandstone is accordingly a rock in which incipient decomposition has resulted in its division into a number of irregularly-shaped aggregates, whose irregularities interlock and hold them together, while the intervening free spaces allow them individually a certain freedom of movement, and to the rock as a whole a certain degree of flexibility within limits governed by the size of the individual aggregates and of the free spaces between them.

Note.—It may not be uninteresting to record here the localities where flexible stone occurs. In America besides Mexico, there are the localities in North and South Georgia and South Carolina. In Europe it is said to have been found in the Rhine valley (*Neu. Jahrb.* 1841, p. 566), in Galicia it occurs *bien caractérisé* (*Bull. Soc. Géol. France*, 1834, p. 416) and it is said to be found in the Ural mountains (*Zeits. Deut. Geol. Ges.* 1849, p. 484), but the term here appears to be used as synonymous with a micaceous quartzite containing diamonds; at p. 487 Baron von Humboldt quotes Jacquemont as an authority for the ocurrence of Itacolumite in India, but he refers to the diamond bearing Vindhyan sandstones of Panna, and not to the flexible stone referred to above, with which Jacquemont does not seem to have been acquainted.

In Asia I know of none but the two localities mentioned in this paper.

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Some other references, which I have not been able to verify, are given in the text-books of Cotta & Lawrence and Zirkel.

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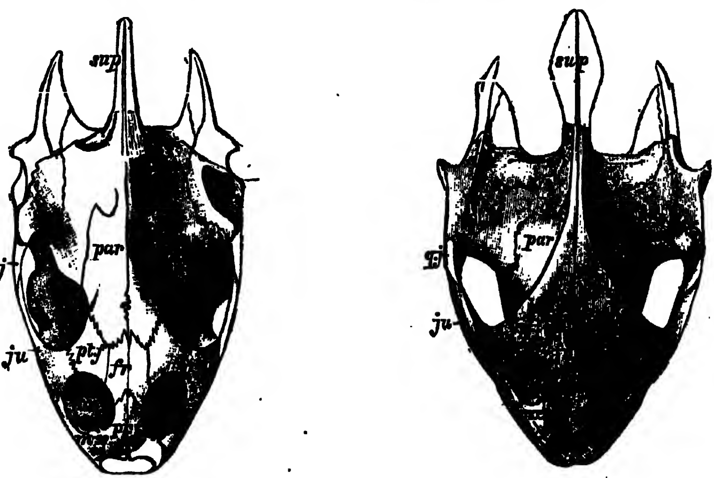
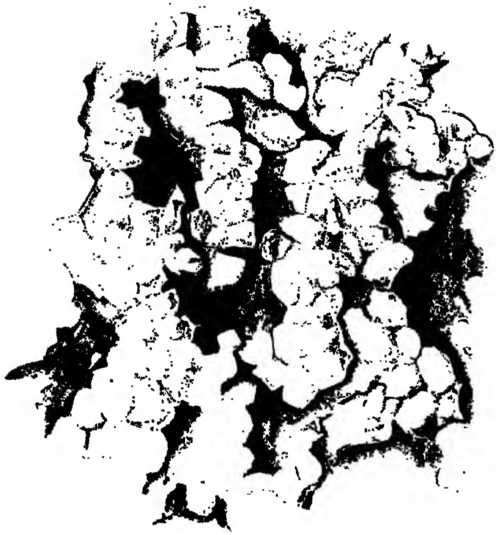
Since it is always desirable in describing fossil Chelonia to have the evidence of the skull as well as that of the shell, I am glad to take the opportunity of figuring the skull of an *Emyda* from the Siwaliks of Perim Island acquired a few years ago by the British Museum, since we have hitherto known this genus in a fossil state solely by the shell. * In order to exhibit the points in which the skull of *Emyda* differs from that of *Trionyx*, I have figured, side by side with that of the former genus, a cranium of *Trionyx gangeticus* from the Pleistocene of the Narbada valley—



A. B.

Frontal aspect of the skulls of (A) *Emyda (cf.) granosa*, and (*B*) *Trionyx gangeticus;* restored and reduced to the same scale. *Sup.* supraoccipital; *par.* parietal; *pt.f.* postfrontal; *fr.* frontal; *pr.f.* prefrontal; *mx.* maxilla; *ju.* jugal; *q.j.* quadratojugal; *or.* orbit.



(× 7)

Fig. I Flexible Sandstone from Kaliana, cut transverse to bedding.

R.D. Oldham, del. Lith[d] by Lala Bindulall.

(× 27)

Fig. 2. Flexible Sandstone from Chárh, cut transverse to bedding.

R. D. Oldham, del. Lith.d by Lala Bindulall.

It will be seen by an inspection of the figures, that the skull of *Emyda* is distinguished from that of *Trionyx* by the much greater deflection of the beak, the larger orbits, the relatively narrower interorbital and postorbital bars, the larger postfrontal, and the generally longer and narrower contour of the entire skull.

The fossil skull agrees in all respects with that of full-grown individuals of *Emyda granosa*, and therefore serves to confirm the identification of the Siwalik shell figured by myself in the 'Palæontologia Indica' with that species. It should, however, be observed that I am unable to distinguish *Emyda granosa* by the characters of the skull alone from the closely allied *E. vittata*; and it is accordingly by no means certain that the skull may not belong to the latter. I refer it, however, provisionally, to the former species, as being the one of which we have definite knowledge in the Siwaliks.

In describing the Siwalik and Narbada Emydines in the "Palæontologia Indica[1]" I have in many instances much difficulty in deciding whether to refer the fossil forms to the existing species to which they were evidently closely allied, or to consider them as representing distinct species. After much hesitation I came to the conclusion to adopt, in most cases, the latter alternative. In the same memoir, owing to the unsatisfactory nature of the definitions of the numerous genera of Indian Emydines proposed by the late Dr. Gray, I decided to employ the generic terms *Clemmys* and *Batagur* in the wide sense in which they are used by Mr. Sclater in his "List of the Animals in the Zoological Society's Gardens."

In recently revising the classification of the Chelonia, the results of which will appear in his forthcoming British Museum Catalogue, Mr. G. A. Boulenger has seen reason to adopt a larger number of genera for the Indian Emydines, and has also arrived at the conclusion that most of the Siwalik forms to which I have applied distinct names are not really separable specifically from their existing allies. As my friend has been good enough to communicate his conclusions to me with permission to publish them, it appears advisable that they should be noticed in the publications of the Survey; since it is useless to retain in our literature so-called species which cannot be defined.

I may add, that when I was describing the Siwalik Chelonia, none of the recent Chelonian shells in the British Museum were stripped of their epidermal shields, so that it was extremely difficult to compare them with those fossils in which only the sutures between the component bones were displayed. Mr. Boulenger has now stripped at least one shell of almost every genus, so that for the future the Palæontologist will have the opportunity of much more exact comparison, and the consequent probability of arriving at a correct conclusion.

Firstly, with regard to the Batagurs, Mr. Boulenger proposes to restrict the term *Batagur* to *B. baska*; and to adopt Gray's names of *Hardella* and *Kachuga* for the other types represented in the Siwaliks which I have included in *Batagur*. There is, consequently, no Siwalik representative of the latter genus. The shells which I have described as *B. falconeri* and *B. cautleyi* are regarded as indistinguishable from the existing *Hardella thurgi*; while Mr. Boulenger also considers that the smaller shell which I described in the 'Quarterly Journal Geol. Soc., Vol. XLII, p. 540, pl. XV, under the name of *Clemmys watsoni*, and considered to be a totally

[1] Series X, vol. iii, part vi (1885).

different form, is really a male of the same species; there being a great difference in the size of the two sexes. I have great hesitation in separating the form I have described as *Batagur bakeri* from *Batagur kachuga* of Gray; and these are now united by Mr. Boulenger as *Kachuga lineata.* There appeared to me to be such a marked difference in the form of the vertebral shields of the shell described as *Batagur durandi* from the allied *B. dhongoka* that I had no hesitation in separating the two forms; but my friend does not consider these differences as of specific value, and accordingly classes both as *Kachuga dhongoka.* The genus *Pangshura* is now included in *Kachuga,* and the species described by Dr. Günther as *P. flaviventus* identified with *Kachuga teetum*: consequently, the fossils which I have referred to *P. flaviventus* should be named *K. teetum.*

For *Clemmys hamiltoni* Mr. Boulenger retains Gray's name of *Damonia,* and if he is right in considering the Siwalik specimens I have figured as *C. palæindica* as not specifically separable from that form, they must be known as *Damonia hamiltoni.* In the group now regarded as generically distinct under the name of *Bellia,* I have described several shells which I referred to four distinct species, under the generic designation of *Clemmys;* Mr. Boulenger informs me, however, that I have regarded sexual characters as specific, and that while the depressed shells are males the vaulted ones are those of female individuals. Under these circumstances, and taking the contour of the nuchal and vertebral shields as affording specific characters, it is probable that we have only two Siwalik species of *Bellia; viz., B. sivalensis = Clemmys hydaspica;* and *B.* (*Clemmys*) *theobaldi = C. punjabiensis.* The form which I have compared with *Clemmys trijuga* will be distinct from the genus *Clemmys* as now restricted.

Finally, in the land tortoises, the observations of Mr. Boulenger tend to show that *Colossochelys* is not generically separable from *Testudo;* while among the Trionychoidea, I am now disposed to regard the unnamed *Trionyx* represented in plate XXVIII, fig. 3, of the Memoir in the 'Palæontologia Indica' as probably belonging to a variety of *T. hurum.*

In the following table the synonymy of the fossil forms according to the above-mentioned views is clearly indicated:—

Batagur	. falconeri, Lyd.	= Hardella thusgi.
———	. cautleyi, Lyd.	
Clemmys	. watsoni, Lyd.	
Batagur	. bakeri, Lyd.	= Kachuga lineata.
———	. durandi, Lyd.	= Kachuga dhongoka.
Pangshura	. flaviventus, Lyd.	= Kachuga teetum.
Clemmys	. palæindica, Lyd.	= Damonia hamiltoni.
———	. hydaspica, Lyd.	= Bellia sivalensis, Theob.
———	. punjabiensis, Lyd.	= Bellia theobaldi, Lyd.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1889. [May.

Note on Indian Steatite, *compiled by* F. R. MALLET, *Superintendent, Geological Survey of India.*

In October, 1887, a "Memorandum regarding the supply of steatite" was drawn up by Mr. J. R. Royle, C.I.E., at the India Office, with special reference to the possible resources of India. Mr. Royle had been applied to by a well-known firm of gas engineers, asking if he could assist them in obtaining from India a material suitable for the manufacture of gas-burners, as they were at that time dependent entirely on Germany for their supply, and the German steatite was then fetching the high price of £17 per ton. The firm in question had, some years ago, received one consignment from India, which answered their purpose perfectly, but they had been unable to obtain any further supply. As it was known, therefore, that good steatite did exist in India, and, further, as the material would be employed in England for many other purposes besides that mentioned above, if a sufficient quantity could be obtained, it was suggested by Mr. Royle that the Government of India should be requested to have samples of good Indian steatite forwarded to London, with particulars as to the supply obtainable, and the local cost.

A copy of the above memorandum was in the following month sent by the Secretary of State to the Government of India, with the suggestion that the necessary samples, and information respecting them, should be collected and sent home to the India Office. The matter having been referred to the Director of the Geological Survey, Dr. King drew up a preliminary note, embodying the information then available. Acting on this, the Governments of Madras, the Central Provinces, and Burma, and the Agents to the Governor General in Central India and Rajputana, were asked to furnish as complete information as could be obtained locally, together with samples of the stone.

Altogether, about 50 specimens (mostly 6 inch cubes) have been received from 38 different localities scattered over 19 districts. Concerning all of these, more or less full information was sent at the same time. The samples and papers having been forwarded to the Geological Survey Office, the work has been assigned to me

of making a preliminary examination of the former and systematizing the information obtained.

As it would be useless to send to England stones that are unfit for employment in any of the uses to which steatite can be applied, all those have been rejected which are obviously worthless. Of these a few are sandstones, the rest being potstones, and steatites so impure as to be valueless, except for such coarse purposes as potstones can be applied to. These rejections include about 30 specimens, leaving 22 specimens from 15 localities in 12 districts. Of these districts, 7 are in the Madras Presidency; the remainder being in the Central Provinces, Rajputana, and Burma.

The specimens last mentioned vary greatly in quality, but none are so bad as to have been deemed worthy of summary rejection. Although the final decision as to which of them are suitable for the purposes of gas engineers must be left to the engineers themselves, an attempt has been made to form some idea on this point in the laboratory here. It appears, from Mr. Royle's memorandum, that the latter stages in the manufacture of gas-burners are performed with circular saws, running at 1,700 revolutions per minute, and that the most minute particles of grit would suffice to destroy both the burners and the saws. As one of the most necessary qualities in the steatite, then, is the capability of being cut into sufficiently small pieces without injury to the saw, it appeared that it would be a fair test to reproduce the actual conditions of manufacture as nearly as could be. A saw two inches in diameter was not obtainable, but one of four inches was used, which was run at about 1,300 revolutions per minute, giving therefore a circumferential speed even greater than that of the two-inch. But this, in as far as injury to the saw itself was concerned, was probably more than balanced by the fact that the larger saw was probably of thicker steel and had stronger teeth. A straight-edge was placed parallel to the saw on one side, and adjustable in its distance, so that slices of steatite of any required thickness could be cut. As a matter of fact, however, all the specimens were tested as to their capacity of being cut into slices ·03 inch thick. Slabs measuring about 4 inches × 1½″ × ½″ were taken, and slices cut from these of 4″ × ½.″ From some specimens, slice after slice of this kind could be cut without breaking. Others, again, gave slices which generally broke in two, while the most brittle samples gave slices which broke up into three or four pieces. These grades are distinguished roughly in the notes below as:—

Cut easily in slices.
Cut in slices.
Cut with difficulty in slices.

At the same time the presence of grit could be detected by the peculiar noise made by the saw, and the feel of the slab in the hand as it was pushed forward.

Previously to their being sent to Calcutta the Madras specimens were tested by Mr. Bosworth-Smith, Mineralogist to the Government of that Presidency, in as far as the means at his disposal allowed.

"It appears," he writes, "that the stone is principally wanted for cutting into caps for gas-burners, but as the demand for stone for such a purpose would of necessity be very small, the economic value of the mineral for other purposes should be given. There are several minor uses to which steatite is put, such as 'marking-

chalk' for tailors, &c. It has been proposed to use the mineral in a fire-proof paint, but with what success I am not aware. Its most general use, however, is as a lubricant, and as this quality can be fairly well tested by rubbing the powdered mineral between the finger and thumb, I have given, in the remarks upon each specimen, a note upon its quality as a lubricant. In determining its capabilities of being cut, but little can be done away from the cutting machine; but as it is clear that grit and a heterogenous structure would be absolutely fatal to its use, I have classed all those specimens that contain grit, and which are not homogeneous, as unfit for cutting. In determining the grit, the method used was to take an ordinary office penknife and cut a small plane on one of the corners of the specimen; then, if on drawing the edge of the knife *backwards* up this streak there were particles of grit loosened, these will scratch the surface of the cut. Such a specimen I have called 'gritty.' If the grit particles could be felt with the edge of the knife when cutting *forwards*, I have termed such a specimen 'very gritty.' On cutting one specimen the grating effect was so great that only the term 'sandy' would apply." Mr. Bosworth-Smith's remarks on the various specimens are quoted in the following notes.

MADRAS PRESIDENCY.

A1.—*From Maddawaram Village, Nandyal Taluk, Kurnool District.*—The specimen from this locality is white, and faint reddish, in color, with a compact structure. Cuts very freely: cuts easily in slices. Mr. Bosworth-Smith says—"This specimen seems the best of those sent in for the required purpose. It does not seem too hard, neither is it over soft. It appears to be remarkably free from grit." The present Director of the Geological Survey, Dr. W. King, who has examined the rock *in situ*, writes,—"Further north still, between Moodwaram (Maddawaram) and Yenkatgerry, the shales of this series[1] are very magnesian, some of the layers being nothing else but fine grey and greenish steatite. There are also seams of the finer form, or French chalk, which is here called, and known over South India, as 'Bulpum.' This Bulpum is largely used by the people as a chalk for writing on their blackened boards, or small folding books of blackened paper or canvas. The associated bands of steatite and steatitic shale, which are of various shades of brown, green, and purple, are carved at Kurnool into paper-weights, &c., * * * This is the quarrying place for steatite in the district."[2]

In the preliminary note alluded to above, Dr. King remarks that "any amount of it (the steatite) can be easily obtained, as it occurs in well-marked bands, or thin beds." "This locality is 22 miles due south of the town of Kurnool." It is four miles distant from the Bethumcherla Railway Station. The Collector of the district gives the "dimensions of the quarries" as one square mile (doubtless meaning that they are scattered over that area), and estimates the cost of delivery at Madras per ton at 20 to 30 rupees, the equivalent of which in sterling is about £1-7 to £2-0.[3] To this must be added the sea-freight. This varies greatly, but at the time of

[1] *i.e.* the Paupugnee beds of the Kadapah formation.
[2] Memoirs, Geological Survey of India, Vol. VIII, p. 166.
[3] Here, and elsewhere, the rupee is taken as equal to 1*s*. 4*d*

writ'ng, would be, by steamer, about 40 shillings per ton (by weight), making the cost of the stone in London about £3-7 to £4-0.[1]

A2.—*Same Locality as* A1.—Color pale green; slightly crystalline in structure. Contains occasional dark red, highly gritty specks of some size, which are minute garnets. Harder to cut than A1, but cuts tolerably freely except where specks are met with, which are *very* gritty: cuts in slices. Mr. Bosworth-Smith remarks that this specimen "does not seem so suitable for cutting as the above; for, on cutting it, the powder seems to clog somewhat. It makes a good lubricant and 'French Chalk' powder."

B1.—*From Pendakallu Village, Ramallakot Taluk, Kurnool District.*—Color pale green; very slightly crystalline in structure. Cuts freely: cuts in slices. "This seems free from grit, is soft and easily cut; does not clog much. Its powder is very greasy and would make a good lubricant" (Bosworth-Smith). The locality is seven miles from the Railway Station. The quarries are stated by the Collector to have the dimensions of (to be scattered over?) 10 acres, and the cost of delivering the stone at Madras is estimated at 20 to 30 rupees (£1-7 to £2-0) a ton, which would be equivalent to about £3-7 to £4-0 in London.

B2.—*Same locality as* B1.—Pale green; somewhat crystalline in structure. Cuts tolerably freely: cuts with difficulty into slices "Very much like the above, but not quite so homogeneous, and therefore not likely to cut so well" (Bosworth-Smith).

G1.—*Somalapuram, Bellary District.*—Pale green; somewhat crystalline in structure. Cuts freely: cuts in slices. "A soft stone; fairly well free from grit; giving a very greasy powder. Seems homogeneous and free from included crystals" (Bosworth-Smith). The Collector of the district remarks that the place is 37 miles from Bellary, and that there are five quarries, of which the smallest measures 8′ × 12′ × 7′, and the largest 12′ × 24′ × 10′. This, and the two following specimens, were probably obtained from different quarries, but it is not so stated. The Collector estimates the cost of delivering the stone at Madras at Rs. 25-1 (£1-13) per ton, to which must be added about £2 for freight to London.

G2.—*Same locality as* G1.—Similar to G1 in color and structure. Cuts freely: cuts in slices. "Similar to above, but in two places tried there was a fairly large piece of grit. Gives a greasy powder" (Bosworth-Smith).

G3.—*Same locality as* G1.—Pale green. Somewhat crystalline in structure, and slightly schistose. Cuts freely: cuts in slices. "A good soft stone free from grit: will make an excellent lubricant and should cut well" (Bosworth-Smith).

Narjampalli of Gulumarri Village, Tadpatri Taluk, Anantapur District.—Yellowish-white and greenish: compact in structure. Cuts very freely: cuts easily in slices. "This is very similar to A1 * *. If not too hard for the cutting machine, it will probably make a serviceable stone, as it is compact and free from grit. It gives a fair lubricating powder, but it is inferior to the softer stones in this respect" (Bosworth-Smith). The quarry is situated in a hill called Balapapurangi Gutta. The stone, according to the Collector, may be had in abundance, but it is not regularly worked. It may, apparently, be inferred from this that pieces are to be obtained much larger than that sent, which only measures 6″ × 1″ × 1″. The Collector esti-

[1] With reference to this, and the following estimates, see remarks on p. 67.

mates the cost of delivering it at Madras at Rs. 28-12-4 (£1-18) a ton, but adds that this is "merely an approximate estimate." It would make the cost in London about £3-18.

L1. *From Pathur Village, Chittoor Taluk, North Arcot.*—Pale green: nearly compact in structure, but traversed by thin veins of crystallized talc, which constitute lines of weakness along which the stone breaks more easily than elsewhere. Rather hard to cut, but free from grit: cuts easily in slices. "This seems a fairly good stone for cutting, as it is free from grit, and seems compact and homogeneous. Its lubricating qualities are only moderate" (Bosworth-Smith). There is one quarry at present. No estimate is given of the cost of delivering the stone at Madras, but the cost of delivering stone from Gangadaranellur, in the same taluk, is put down by the Collector at Rs. 7-8-0 (10*s.*) a ton, to which must be added the sea-freight.

C1. *From Eswaramalai Hills, Atur Taluk, Salem District.*—Pale green: finely crystalline in structure: contains disseminated crystals of dolomite, which are occasionally as much as $\frac{1}{4}$ inch long. Gritty in cutting: cuts with difficulty in slices. "This specimen is found slightly gritty on cutting. It contains some calcite. Its powder, when free from grit, makes an excellent lubricant" (Bosworth-Smith). The Collector states that there are three quarries, the smallest of which measures $9' \times 9' \times 9'$, and the largest $33' \times 21' \times 42'$, besides several smaller pits at the foot of the hills. He estimates the cost of delivery at Madras at Rs. 20 to 25 per 50 Madras maunds, or a little over half a ton—say Rs. 40 to 50 (£2-13 to £3-6) a ton, which would make the cost in London about £4-13 to £5-6.

C2. *Same locality as* C1.—Pale green: finely crystalline. Contains numerous, small disseminated crystals of a chloritic mineral, and minute acicular colorless crystals (tremolite ?). Gritty: cuts with some difficulty in slices. "Similar to above but rather more gritty" (Bosworth-Smith).

E2. *Edamaranahalli village, Kollegal Taluk, Coimbatore District.*—Pale green: finely crystalline: contains minute chloritic crystals. Rather gritty in cutting: cuts in slices. "Distinctly *sandy* to the cut. Powder greasy, but with gritty particles" (Bosworth-Smith). The stone is obtained in the hills near the village. No estimate of cost is given.

E3. *Kollegal Taluk, Coimbatore District.*—Reddish-white and greyish: finely crystalline. Cuts tolerably freely: cuts easily in slices. "Gritty to cut. The powder is very greasy, and would make a good lubricant if grit were removed. The specimen is thin, and not up to the required size" (Bosworth-Smith). It is not clear whether this specimen is from the same village as E2, or from a different one, and it is not stated whether pieces thicker than that sent ($1\frac{1}{2}$ inch) can be obtained.

K4. *Manavalike village, Nerankimagane, Uppinangadi Taluk, South Canara District.*—Pale buff, with reddish specks in places: schistose. Cuts very freely: cuts easily in slices parallel to the foliation, but not across it. "A rather hard stone, free from grit and may do for cutting, but will not do for lubricant" (Bosworth-Smith). The specimen sent is a small one, about 2 inches thick, and it is not stated whether larger ones can be obtained. The Collector puts down the dimensions of the quarry or quarries as 600 square yards, and estimates the cost of delivery at Madras at Rs. 20-2-0 (£1-7) a ton, which would be equivalent to about £3-7 in London.

CENTRAL PROVINCES.

No. 6.—*Kanhcri Village, Sakoli Tahsil, Bhandara District.*—Color buff: crystalline in structure, and intersected by occasional thin veins of crystallized talc, along which the stone breaks easily. Cuts very freely: cuts easily in slices if free from veins: powder very greasy. The local authorities say that there is a large quarry which is extensively worked, the stone being largely used for making vessels. The cost of quarrying is roughly estimated at Rs. 2 a ton, and that of the cartage to the railway (27 miles) at Rs. 6. The railway charge to Bombay would be Rs. 25-12, giving a total at the port of Rs. 33-12 or £2-5. To this must be added the sea-freight, which, at the present time, would be, by steamer, about 30 shillings per ton (by weight), making the cost in London about £3-15.

No. 1.—*Marble Rocks, Jabalpur District.*—White, with pale reddish blotches here and there: somewhat schistose. Cuts very freely: cuts easily in slices with the foliation, but with difficulty across it: powder very greasy. Dr. King writes—"I know of this steatite myself, and have seen the people grubbing it from the pockets in the Marble Rock dolomite and schists. The rocks about there are much crushed and twisted, the steatite having, in this way, been stretched and squeezed into irregular pockets, which of course, in case of more extended exploitation in depth, will be difficult to get at. At present there seems quite enough of the material, either at the surface or close to it, for the purpose required." According to the local authorities—"The extent of supply cannot be given with certainty. The steatite is found in irregular pockets, imbedded in limestones and schists. As the local demand is inconsiderable, the quarries have not been as yet worked on any large scale, but it is said that some thousands of maunds[1] can be made readily available. If the specimens now sent are up to commercial standard, the only doubt which can arise is, not whether the local supply is sufficient, but whether (having regard to the peculiar formation) it will be feasible to extract blocks of the size required." The cost of quarrying is roughly estimated at Rs. 2 a ton, and that of cartage to the railway (3 miles) at R1-12-0. Adding to this R28-7-0, for railway carriage, gives a total at Bombay of R32-3-0 (£2-3), or, with sea-freight, about £3-13 in London.

RAJPUTANA.

Mora Village, 15 miles north-west of Hindaun, State of Jaipur.—Pale green: very finely crystalline, and somewhat schistose, in structure. Cuts very freely: cuts easily in slices parallel to the foliation; more difficultly across it: powder very greasy. This is the material so much used at Agra for manufacturing elaborately carved ornamental articles. Mr. C. A. Hacket describes the stone as occurring in a bed (intercalated with quartzites of the Arvali series) which varies in thickness, but averages 2 feet, and which dips at about 30°, the outcrop being on the side of a hill, 150 feet above the plain. The quality of the material varies, but cubes of pure stone of 12 to 18 inches can be obtained. It is not excavated from open quarries, but from rude mines, the entrances to which are inclines following the dip of the bed. The mines are only worked in the dry season. and then intermittently, when the merchants from Agra arrive with orders, the total of which amounts on an average to 1,500 maunds

[1] 27·2 maunds = 1 ton.

(55 tons) per annum. The cost per maund of delivering the stone at Mora (1 mile from the mines) was given by the head villagers to Mr. Hacket as follows:—[1]

	a.	p.
To the khatis or miners	1	0
Carriers from mine to Mora	2	0
Zamindar of Mora	2	0
Sonar, or broker (financier)	0	6
Chowkidar of village	0	6
Chowkidar on guard	0	6
Putwari for weighing	0	6
Village charities	0	3
Maharaja of Jaipur (royalty)	3	0
Total cost delivered at Mora	10	3

According to information given to the Executive Engineer of Jaipur, the cost at the mine is 2 annas a maund, but this apparently refers to the cost of extraction only. The rate for cartage to Hindaun Road railway station is estimated at 6 annas, the railway charge to Bombay being R1-7-1. Adopting Mr. Hacket's figures this gives—

	R	a.	p.
Cost at Mora	0	10	3
Cartage to Hindaun Road Station	0	6	0
Railway carriage to Bombay	1	7	1
Cost per maund at Bombay	2	7	4

which is equivalent to R66-15-0 or £4-9 per ton, or to about £5-19 in London.

Raiwala (or Raialo) Village, 15 miles north of Jatwara Railway Station, Jaipur State.—White, with occasional reddish markings: nearly compact (slightly crystalline) in structure. Cuts very freely: cuts easily in slices: powder very greasy. According to information obtained for the Executive Engineer of Jaipur, there are 3 quarries, with the following dimensions—

Length.	Breadth.	Depth.
800′	30′	15′
300	30	?
450	50	?

It is added, however, that "these quarries are apparently of dimensions stated, but, not having been opened out, it is impossible to speak with certainty as to extent or quality." "We have never worked these quarries; the information is therefore necessarily imperfect." It would appear from this that the figures given must refer to the supposed extent of the soapstone deposit, not to that of existent quarries. As the place is some 7 or 8 miles nearer the railway than Mora, and involves about 30 miles less railway carriage, the charges for delivering the stone at Bombay may probably be taken as about the same, or slightly less.

Gisgarh Village, Jaipur State.—Green: highly schistose in structure. Rather gritty in cutting, but cuts easily in slices, except across the direction of foliation.

[1] Manual of the Geology of India, Part III, p. 443.

According to information obtained for the Executive Engineer of Jaipur, the quarry is 200 feet long, 3 feet wide, and 2 feet deep, from which it may be inferred that it extends along the outcrop of a bed having a rather high dip. Slabs can be obtained of large size, but not more than 2½ or 3 inches thick. The cost per maund of delivering the stone at Bombay is estimated as follows—

	R	a.	p.
Cost at Gisgarh	0	4	0
Cartage to Bandakari Station	0	4	0
Railway carriage to Bombay	1	6	6
Cost at Bombay	1	14	6

This is equivalent to R51-14 (£3-9) per ton, or to about £4-19 in London.

BURMA.

Myingudé Mountain, Yoma Range, Kyaukpyu District,—Pale green, but contaminated a good deal with ferruginous impurity: compact in structure. The purer pieces cut freely: cuts easily in slices. The Native Extra Assistant Commissioner at An writes—"I have the honor to report my visit to the soapstone mines at the Myingudé Mountain, which (the mines) are evidently on our side of the Yoma Range, and on a small hill joining the Myingudé Mountain. Last year the Burmese from Upper Burma dug six mines on our side and two on theirs. As these soapstones are to be found between other stones, it is very difficult to know the approximate yield of the mines. I am, however, informed that the Burmese who dug the mines last year received about 5,000 *viss*.[1] A hundred *viss* of first quality will fetch at An Rs. 70 or Rs. 80 at least; of the second Rs. 50 or Rs. 60. The greatest depth of the mines dug last year is 8 cubits. Having discovered soapstones all over the hill, I hope to find more mines, but the discovery, and the production of them, entirely depend on the amount of labor employed." The specimens sent to Calcutta are only about an inch square by 4 or 5 inches long. It is not stated whether larger can be obtained, but as Mr. Theobald, speaking of the steatite of the Arakan Hills generally, says that the veins are usually of small dimensions,[2] probably the pieces in question are fair samples of what can be procured. The rates given above are equivalent to—

	Rs.		Rs.		£	s.		£	s.
First quality, per ton,	429	to	491	or	28	12	to	32	15
Second " "	307	"	368	"	20	9	"	24	11

To this has to be added carriage from An, by river, creek and sea to Akyab (estimate for which is not given), and freight from Akyab to London, so that the stone would be far more expensive in England than that from Germany.

It may be suspected that the very high prices quoted are due in part to much of the stone being of inferior quality, so that only a small portion of that extracted is saleable. The remote position of the mines or quarries, and the high rates paid for labor in Burma, also tend to raise the cost.

[1] About 8 tons.

[2] Memoirs, Geol. Survey of India, Vol. X, p. 336.

Hills behind Pa-aing, Sidôktaya Township, Minbu District.—Pale green: compact in structure: cuts freely. The pieces sent are only $\frac{1}{4}$ or $\frac{3}{8}$ inch square by 2 or 3 inches long, and it is not stated if larger can be obtained. Concerning this stone the Deputy Commissioner writes—"It is not exactly known how much there is, but the revenue paid for the quarry license this year was Rs. 2,300, so probably there is a good deal. We have been such a short time in the country that we have not been able to investigate the quarries, which are right up in the hills away from villages, I understand. It is procurable at Sidôktaya at Rs. 80 to Rs. 85 a 100 *viss* (365 lbs.), and has then to be carted about 50 miles to the river. This would cost another Rs. 5 or so. The steamer charges to Rangoon (about Rs. 15 a ton of 50 cubic feet) have then to be borne." The price at Sidôktaya given above is equal to Rs. 491 to Rs. 521 (£32-15 to £34-15) a ton, a rate which would be quite prohibitive, in as far as export to England is concerned.

Although, as previously remarked, the final selection of the most suitable material must be left to the gas engineers themselves, it will, I think, be found that the variety like A1, from Maddawaram in Kurnool, and the stones from Gulumarri in the Anantapur District, and Raiwala in Jaipur, are amongst the best, while several other samples appear to be very promising. But it has been pointed out by Dr. King in his preliminary note that a difficulty is likely to arise in the first instance with reference to the due selection of the best stone. "It is this difficulty of selection which must introduce a considerable factor in the cost of the stone as placed in the English market, for I fear that for some time the native quarrymen and contractors cannot be depended on for sending well-selected stone." Dr. King adds that a European, and preferably one from the German quarries, in charge, would be highly desirable, were it not that owing to the comparatively small demand now existing for steatite in England, the nascent industry would not be able to support the expense. As a practicable alternative, therefore, Dr. King suggests that natives might be obtained from some of the existing quarries, who, after some training, would be competent to make a proper choice. Mora, in Jaipur, would probably be the most likely place to seek such overseers. The steatite there varies in quality, but the demand at Agra for the best material has led to the acquirement of the necessary skill in selection on the part of those engaged in the work.

It is not clear whether the estimates for quarrying given by the various District authorities include manual labor only, or whether provision is made for supervision. Royalty, also, does not seem to be allowed for. An addition ought further to be made to the estimates, on account of expenses connected with breaking bulk at the railway, and at the ports of shipment and delivery, as well as, perhaps, on account of some incidental charges. But even if a liberal allowance be made under such heads, it appears clear that the steatite from every locality mentioned, except those in Burma, can be delivered in London at prices far below that now paid for continental stone. When the gas engineers have made their final selection, the export of a trial consignment will lead to more closely accurate information than is available at present, as to the cost of delivering the material in England.

Distorted pebbles *in the* Siwalik conglomerate; *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.* (With one plate.)

A curious case of pebble distortion in the soft Upper Siwalik conglomerate has just come under my notice. It occurs near the axis of a small synclinal about one mile up the Raiála gád, Sara N., in E. Kumaun. The conglomerate here is composed, as generally, of a very large percentage of quartzite pebbles, grey and white in colour, with a few (more numerous, however, than I have elsewhere noticed) granite and trap pebbles. All these rocks, which are well-rounded and somewhat smaller than a cricket-ball, are closely packed together in a slightly coherent sandy matrix, not harder than what is ordinarily known as sand-rock. There is no cementing calcareous material here, as is present in many places.

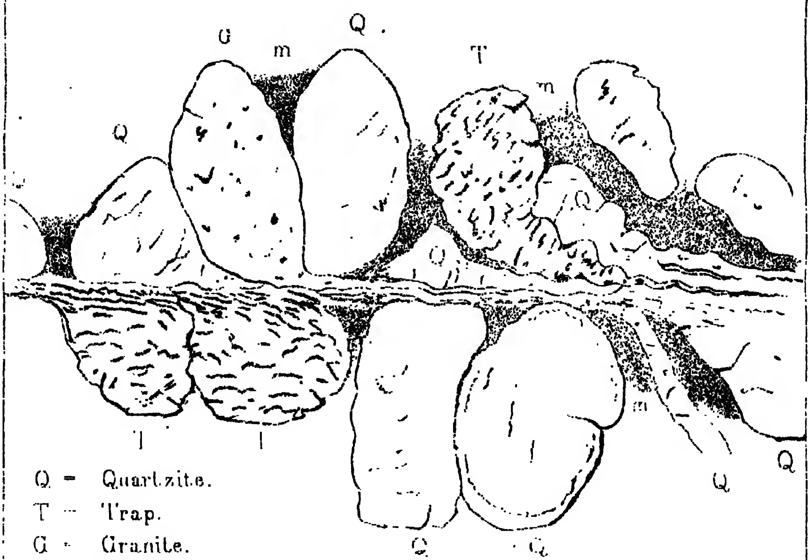
The diagram forming the upper figure of the accompanying plate represents a nearly horizontal plane of division, having much the appearance of a slickensides, which cuts through the Siwalik conglomerate in this one place where I have observed it. But the remarkable attendant fact concerning it is that many of the pebbles above and below the slickensides have been crushed or drawn out in the direction of the plane of division. At the left upper side of the diagram there is first a quartzite pebble, split and shivered into plates and needles, and drawn out into a finely tapered process of pounded quartz. Next to that is one of granite, an ordinary typical granite, of the kind found *in situ* immediately to the north of the main-boundary (reversed fault between the Tertiary and Himalayan rocks) and which was in company with the trap erroneously ascribed by General Strachey [1] as intrusive in the Tertiaries in the Gola R. This pebble displays a process tailing off into a very thin filament, as long as the pebble itself. The next quartzite pebble is very dense and is merely in a fractured and splintered condition. Next to this come three pebbles, two of quartzite, with one of trap between them. Each of these has been crushed and drawn out into wavy, sinuous bands, resembling those of a puckered schist. A similar set of pebbles beneath the plane of division shows analogous features, the drawing out, however, being in the opposite direction.

This somewhat extraordinary local shearing appears at first sight easily explained. Even the youngest members of the Sub-Himalayan series have been folded and reflexed to a very great extent, as I have depicted in a forthcoming memoir. It seems rational, therefore, to impute the above feature to the action of the forces which brought about that folding and reflexing of the rocks. But against this is to be set the fact that it is a very rare feature, not by any means universal, as is much of the overfolding of the Sub-Himalayan zone. The Siwalik conglomerate is not cut through by numberless sets of these divisional planes, and it can hardly, therefore, be placed in the same category as those foliated granites, traps, and other rocks of the older Himalaya which evince dynamic metamorphism on a microscopic scale through great thicknesses of the rock.

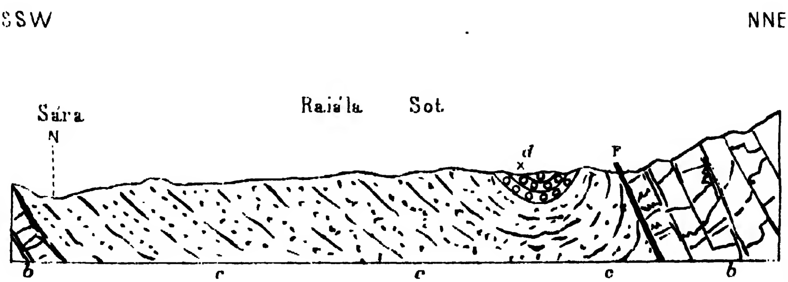
The first effect of dynamic metamorphism of rocks of this kind we should expect to be a compacting and hardening of the finer material, a conversion of the

[1] Q. J. G. S. Lond. 1851, Vol. VII, p. 296.

Middlemiss.



Q = Quartzite.
T — Trap.
G - Granite.
m — Matrix of sand.



Section in which the above occurs.

d - U. Siwalik cong^l^
c - M. do. Sand-rock
b - L (Nahan) Sandstone
x = Position of distorted pebbles.

Lith^d by Lala Bindulall.

matrix into something more rigid than a sand-rock capable of being dug with a spade.

But a study of the Himalaya is for ever forcing on one the inadequacy of general and sweeping theories. Contrary to what has been recently demonstrated by M. B. Lotti in the Apennines[1] where hardening and metamorphism of the Tertiaries have been connected with violent contortion of the strata, we have everywhere along the Sub-Himalaya evidence of great sigmaflexures and thrusts, occurring in the Upper and Middle Siwaliks, without in the least altering the texture of the soft clays, loams and sands of which they are composed. Everywhere material of the nature of the *molasse*, though forming gigantic folds, is as unmetamorphosed as that which M. Lotti describes in the undisturbed parts of Italy.

The Carboniferous Glacial Period."[2] *Further Note*[3] *by* DR. W. WAAGEN, *on a letter from* MR. C. DERBY, *concerning traces of a Carboniferous Glacial Period in* S. America. *Translated by* E. C. COTES, *Asst. Supdt., Indian Museum.*

The following extract from a letter, dated 16th April 1888, from Mr. Orville A. Derby, Director of the Geological Section Museo Nacional, Rio de Janeiro, appears to be of sufficient interest to be worth bringing to notice in Europe :—

"Your statement (Aufsatz über Carbone Eiszeit) that no traces exist in South America of ice during the carboniferous period, rests rather on want of observations, in the eastern portion of the continent, than on the actual absence of the phenomena, which have been observed in Australia, India, and South Africa.

"In South Brazil is a large palaeozoic area, which includes a large portion of the Parana basin, about which, however, practically nothing has yet been published. So far as I know, the only publication which exists, besides scanty papers on the Coal beds of Rio Grande do Sul by Weise, Plant, Carruthers and Hartt, is my own little treatise on the diamond region of the province of Parana (Proc. Am. Phil. Soc. 1879), and the very slight geological information contained in my two Geographical sketches written in Portuguese; one of these, *viz.*, 'Phisikalische Geographie u. Geologie Braziliens,' which was intended for a school book in Abren and Cabral, has also been printed in the Mittheilungen der Geographischen Gesellschaft für Thüringen; the other, *viz.*, 'Contribuição para o Estudio da Geographia Physica do valle di Rio grande' appeared in the Bulletino da Sociedade de Geographia de Rio de Janeiro, Vol. I, No. 4. In a section through a portion of the province of Parana, which may serve as typical of the geological structure of the eastern side of this formation, we find a mountainous outer border (chiefly composed of crystalline rocks) and two broad terraces of horizontal strata. The first of these two terraces is composed of sandstone and clay slate, which belong partly to carboniferous, partly to Devonian formations. At Ponta Grossa these rocks have yielded fossils of Devonian type, *e.g.*, *Lingula*, *Discina*, *Spirifer*, *Rhynchonella*, *Vitulina*, *Streptorhynchus*, and *Homalonotus*; while at Colonia Hueza, at the foot of the second terrace, have been found such Carboniferous types as *Myalina*, *Schizodus*, *Lepidodendron* (often leaves), *Cordaites*, and *Psaronius*. The second terrace is composed of soft red sandstone and bedded trap (augite-porphyry), and is probably of Permian or Triassic age. Towards the west this formation

[1] See Extrait du bulletin de la société géologique de France, 3e Série, t. XVI, p. 406.
[2] See Records, Geol. Survey of India, Vol. XXI, p. 89.
[3] Neues. Jahrb f. Min. Bd. II, 1888, pp. 172-77.

stretches up to and beyond Parana, and can be traced, by its characteristic eruptive rocks, from Montevideo to the neighbourhood of the springs of Parana.

"Further to the south, in the province of Santa Catharina, the mountain chain becomes lower and the steep descent of the third division, of the profile, which is the watershed between the Uruguay and the Atlantic Ocean, approaches the sea-coast and appears to form the continuation of the Serra do Mar. In Rio Grande do Sul and in the Republic of Uruguay, it retreats further inland, at the same time losing its character of watershed. The district, traversed by the rivers flowing straight into the Atlantic Ocean, is occupied by beds denuded from the first and second divisions of the Parana profile. The Devonian formation has not as yet been traced south of the province of Parana, though it would be premature to assert its non-existence.

"Towards the north, in the province of São Paulo, the profile is similar to that of Parana: the Devonian, however, does not appear. In the southern portion of Minas Gereas, near the boundary of the province, the second (upper palaeozoic) zone disappears, and the soft sandstone and volcanics of the third zone lie directly on the metamorphics and crystallines, which belong to the first zone and compose, towards the west, the district of the springs of São Francisco. From this neighbourhood northwards, is a gap in our knowledge of the geological conditions, and it is only further towards the north-west, in the Paraguay uplands, that we again reach territory of which something is known. According to the communications of Mr. H. H. Smith, and from the fossils which he has forwarded, it would seem that Devonian, and also probably carboniferous, formations occur here, overlaid by beds containing large reptiles probably of mesozoic age. We may hope that your fellow-countryman, Dr. Vogel, who accompanied the Van den Steinen Expedition to the springs of the Xingù, and who is expected to return in a few weeks, will be able to give us further information about this neighbourhood. And it may be taken as probable that the Parana and São Paulo formations extend up to, and beyond, the Parana upland, and are connected with similar formations in Tocantin Xingú and Tapajos. However this may be, so much is certain that a broad girdle of upper palaeozoic formations (Carboniferous Permian or both) exists, and spreads itself over a great part of the length of the Parana basin.

"I have personally visited a large portion of this region, in the provinces of Parana and São Paulo, though I have been unable to examine it carefully. One of my assistants, however, found his way there through Monate; his object being to investigate parts of the province of São Paulo, and specially to observe the collections of fossils, which are somewhat scarce. The rocks are generally soft red and yellow sandstones, with reddish black clay slates. And the strata, which are occasionally thin, contain an impure coal, and one considerable limestone bed, which is full of flints. It is in this limestone bed, and its immediate neighbourhood, that all the fossils have been found.

"The most common fossil is that of a reptile described by Cope (Proc. Am. Phil. Soc. 1886) as *Stercosternum tumidum*, a new genus of Permian type; after this come various fossil woods, generally conifera of *Dadoxylon* type, though specimens with regular pittings also occur; then stems and leaves of *Lepidodendron*, with here and there fragments of *Psaronius* stems. Remains of Mollusca are rare and generally fragmentary, bivalves are the only ones that have yet been observed, and amongst these *Schizodus* and *Myalina* can be recognized, with some certainty, while the determination of other remains (*e.g. Conocardium*) is doubtful. In addition to the above a few small fishes' teeth and scales have been found, but nothing more. In this case, therefore, unaccountable as it may appear, the various common Carboniferous types are either altogether absent, or at least are very difficult to find.

"There is but one fossil-bearing bed known in the province of Parana, and that has only been cursorally examined. Unfortunately my own collections from the place have been lost; the specimens, however, only comprised a few bivalve mussels, in a better state of preservation, but probably specifically identical with, some of those of the São Paulo fossils which have been recognized. Besides these, however, fossil wood has been found in various localities, and fossil ferns also are mentioned, though I myself have not met with them.

"We thus see, in the rarity of the fossils, and in the general character of those which have been found, a certain similarity between the carboniferous of South Brazil and that of Australia, India, and South Africa. There are also other phenomena which have never yet been critically examined; I allude to those so appositely described by yourself and others as due to the action of ice.

"I usually make my geological tours here by rail, and, as I traversed the province of São Paulo in this way, I saw in the railway cuttings rounded blocks, varying from the size of a man's fist to four times that of his head: these were imbedded in, and protruded from, particularlyfine clay slate. On the river Juté, near the town of Itú, is a large flagstone quarry, situated in an unusually fine sandy clay slate, which contains isolated, rounded blocks of granite, gneiss, &c., ranging up to and above, eighteen inches in diameter. Similar phenomena have also been observed near the town of Itapetininga. Last year I asked my assistant, Dr. Gonzaga de Campos, to direct his attention especially to these stones, and he has discovered some more localities in which they occur. The most interesting of these is the ravine of Capavary, near the spot where the streamlet of this name flows into the Juté, and a few miles below the town of Itú, which I have mentioned above. Here, in the bed of the streamlet, between clay slate banks lies a group of large blocks. Some years ago, when I saw these blocks myself, I thought they must be an outcrop of granite or gneiss, washed bare by the stream; Dr. Campos, however, informs me that they are of various kinds of stone, and, as far as he can make out, rest upon clay slate, but as their bases were covered with water, it is just possible that he may have been mistaken. Some of these blocks are more than a yard in diameter, and the fragments, broken from them, showed a gneiss, a fine-grained granite, and a hard coarse conglomerate. The collection of so large a quantity of different kinds of stone, combined with the fact that the clay slate of the banks, in the immediate neighbourhood, contained a great quantity of smaller block, points to the fact of their having been transported.

"The fact of the occurrence of large transported blocks, in the carboniferous of Brazil, is consequently sufficiently established, and the conditions of their occurrence seem to exclude the possibility of their having been brought by the action of a river or sea. It is true, indeed, that no scratched surfaces have yet been observed on the blocks, but, on the other hand, it must be remembered that no geologist, with a trained eye for such marks, has yet examined them.

"In the surveying of the province of São Paulo, which will now pass under my direction, I shall pay particular attention to these phenomena, and hope hereafter to be able to give more exact particulars of them. In the meantime you can make whatever use you think best of the bove remarks."

The interesting indications, given by Mr. Derby's letter, of the occurrence in Brazil of phenomena which have already been observed in so many places in the southern hemisphere, encourage the supposition of their universality—a hypothesis already put forward, though not yet established.

The belief is spreading that it is ice which has heaped up the masses of transported blocks which are met with everywhere in the southern hemisphere; and the wide distribution of the phenomenon points clearly to a cosmic event, for which the most satisfactory explanation is that of an ice age. Mr. Derby's discovery therefore is of extraordinary importance, and he will earn the thanks of the scientific world if he devotes close attention to the matter.

The resemblance between the structures met with in the geological formations in South America, Australia, and South Africa, does not seem to be confined to the fact that glacial formations exist in their carboniferous. This is indicated in Szajnocha's notice (verhandl. K. K. Geol. Reichsanstalt), where the following Australian-African-Indian species are enumerated as also occurring in Cacheuta in the Argentine province of Mendoza:—

Estheria Mangaliensis, Jones.
Sphenopteris elongata, Carruthers.
Sphenopteris lobifolia, Morris.
Thinfeldia odontopteroides, Morr.
Thinfeldia lancifolia, Morr.
Zeugophyllites elongatees, Morr.

Notes on DR. W. WAAGEN'S "Carboniferous Glacial Period," by A. B. WYNNE, F. G. S., and DR. OTTOKAR FEISTMANTEL.[1]

When this paper[2] first reached me I noticed Dr. Waagen's allusions in it to myself and decided to let them pass, as already, by anticipation, dealt with. But on reading them again, and without the slightest present intention of further recurring to the subject, I think it may be well, for the sake of establishing facts or avoiding unnecessary appearances of more controversy than these would warrant, to offer a few observations upon his references to the "Geology of the Salt Range." At page 115 the translation says, of the Report on the Salt Range compiled by myself, "that it should have been a joint one, but this was prevented by his serious illnesses, and thus Wynne was compelled to undertake the working out of it by himself."

This is quite accurate; but he should have added that the matter was very fully discussed by us (in my bungalow at Murree), and the classification of the rocks was arranged between us, even to the details of sections examined by him, and read by him from his note-book, while I transcribed them as they appear in the Report. Instead of any such statement I quote the passage immediately following that already given :—

"The employment of the material has, in consequence, often led to the different results, as if I would have disposed of them could I have influenced their being worked out. I cannot, however, for that reason entirely give up my own views, and Mr. Wynne must allow me to give them expression here and there."

And a few lines further on, "But now if, after having worked out the fossil faunas of the Salt Range in a great measure, I find myself constrained to lay yet greater stress on various points in the apprehension of which I did not agree with Mr. Wynne, it will be owing to the progress made through the more exact understanding, palæontologically, of the beds."

Dr. Waagen is quite entitled to give every expression to his views, but, having arrived at further palæontological knowledge in working out the fossils, he is not entitled, as he has hitherto done, to evade his own responsibility for the statements of the Report, and in repudiating them where it was convenient to throw the onus of what he considered erroneous views upon me.

Dr. Waagen was most fully acquainted with all of my conclusions, and if he then held opinions to the contrary, it was the time to declare and record them. Any views of his not obvious to both were given mainly from the palæontological point of view; mine rested upon structural relations: both should coincide, and both might of course be open to revision, but the insinuation conveyed in the passage quoted as to the "material"—presumably that left with me—having been distorted from his views, or in any way misused, is utterly misleading.

Some of my conclusions as to the range or horizons of the boulder beds have

[1] These notes are, I regret to find, somewhat controversial, and I think, hardly necessary on the trivial points in Dr. Waagen's paper which are questioned, or of value in the discussion of the greater feature of a carboniferous glacial period. The pity of it is that the writers are so far out of reach, and this is the only reason for these remonstrances of my two friends and former colleagues having a place in these Records, in which, as a rule, controversy should be avoided.—EDITOR.

[2] See Vol. XXI, p. 89.

been revised by Dr. Warth (and afterwards by Dr. King) from personal observation and discovery of a fossiliferous *Conularia* layer in ground complicated by landslips. It is perfectly possible that the conclusions to which Dr. Warth has been led are quite correct, and if I had got the clue he found I have no doubt I should have followed it in the same spirit and intention to reach the facts.

With regard to Dr. Waagen's remarks, pp. 118 and 119, upon the rolled fossiliferous pebbles which he calls "nodules" in the *Conularia* layer, I cannot consider the description of the case adduced as invalidating the conclusions of Mr. Oldham and myself.

A few explanatory notes regarding the history of the Karharbari Flora, by OTTOKAR FEISTMANTEL, M.D.

Part 3 of Vol. XXI of the Records of the Geological Survey of India contains an interesting paper by Dr. Waagen, "The Carboniferous Glacial Period," a translation of the same paper in the "Jahrb. K. K. Geolog. Reichsanstalt," Vienna, 1887. I would now ask to be allowed to make a few remarks to that part of the paper where Dr. Waagen speaks of the *Karharbari* Flora (l.c., 93-94). Dr. Waagen relates how in 1871 he visited, together with Dr. Stoliczka, the coal-field, that they observed well-preserved plant-remains, "a real joy to the eye of a palæontologist," but that the harvest was not a great one, the more as the rock was so cracked that it crumbled away under the lightest touch of chisel or hammer; they however received some specimens by Mr. Heine, then Manager of the collieries, so that they did not depart empty-handed; of these Prof. Waagen writes (l. c., p. 94), "*The specimens then procured formed the chief basis for Feistmantel's descriptions.*"

Had there been no other specimens but these the Karharbari Flora would, I think, have proved a very poor one, and *I can indeed say that it would hardly have been established as such on the basis of these fossils only.*

It is only doing justice to myself, and also to Mr. I. T. Whitty, C.E., late Superintendent of Karharbari collieries, East India Railway, when I shortly relate the history of the Karharbari Flora, that it may for ever be preserved in these Records.

The fact is, that the *first impulse* to our knowledge of this most interesting Flora was given by Mr. I. T. Whitty, C.E., who early in 1876, while I was engaged in working out the Kach Flora, brought to the Geological Survey, Calcutta, a magnificent slab of shale, from the *Buriadi* coal mines, containing, as it were, the nucleus of the entire Flora, afterwards made known. (See Preface, Vol. III, Gondwana Flora, page iv.) The species contained on that big slab were at first noticed and described by myself in Records, Geological Survey, India, Vol. IX, pt. 3 (August 1876), pp. 73, 75 and 77.[1] I had then no knowledge whatever of any fossils from the Karharbari coal-field being already in the Survey collections; I would have otherwise certainly included them in my just-mentioned paper.

The circumstance, however, that Mr. Blanford published in the same number of the Records, a paper calling in question the general value of geological

[1] The species were: *Neuropteris valida*, Fstm., figured afterwards in the Karharbari Flora, 1879, Pl. VI, f. 1, 2, 5 (fine, large specimens); *Gangamopteris cyclopteroides*, Fstm., l. c., Pl. XXVI, f. 1; *Voltzia heterophylla*, Bgt., l. c., Pl. XXV, f. 1-3; *Albertia* sp., l. c., Pl., XXVI, f. 2. In my above-mentioned paper the *Voltzia* was at first quoted as *Voltzia acutifolia*, Bgt., but hereafter placed with *Voltzia heterophylla*.

homotaxis as drawn from the fossil remains of terrestrial life, and based upon an analysis of the evidence for the age of the Gondwána series, induced me to look more thoroughly also over the collections of the Lower Gondwana fossils, and *only then* some Karharbari (Kurhurbali) fossils turned up, which were duly noticed in my next paper, Records, Geological Survey of India, Vol. IX, Pt. 4 (November 1876).

The fossils thus discovered were from two localities of that coal-field, and were also collected at two different times. One lot contained plant-remains, rather indistinctly preserved on a light grey, weathered-looking shale: they were from Passerabhia, and, as it appeared, were collected by Mr. Wilson (1859); I referred to them passingly in my Talchir-Karharbari Flora, 1879, p. 39 (under Passerabhia, No. 5, D); but they were of no avail, as no horizon was marked and the fossils themselves were very indistinct; none of them could be figured.

The other lot was marked "*Domahni Ghat, Dr. Stoliczka, 1871.*" The fossils were in a dark grey, fine micaceous shale, and themselves covered with a thin coal-stratum. *These, I suppose, must be the fossils Dr. Waagen refers to;* I referred to them several times in my paper in Records, Geological Survey, India, Vol. IX, Pt. 4, everywhere mentioning that they were brought by Dr. Stoliczka, 1871; Dr. Waagen's name was not marked there, otherwise I would have mentioned it also. The most prominent of the fossils I have named and described were *Gangamopteris angustifolia*, McCoy (one leaflet); *Sagenopteris Stoliczkana*, Fstm. (one frond); *Glossozamites Stoliczkanus*, Fstm. (two leaves); and *Voltzia heterophylla*, Bgt. (three branchlets).

But all these specimens, though very interesting, could not furnish sufficient material for a monograph of the fossils of that horizon, and they were up to then treated as fossils of the Damudas.

Only after I had visited the field, in January 1877, when I made, with the assistance of Mr. I. T. Whitty and Mr. N. Miller, Inspector of Collieries, extensive collections from various localities, the character of the Karharbari Flora manifested itself, and in a short note in Records, Geological Survey, India, Vol. X, Pt. 3, 1877 (pp. 137-139), I pointed to the strong relation of the Karharbari Flora to that of the Talchirs.

Mr. Whitty and Mr. Miller continued to send further valuable information about fossils and geological relations, so that the Karharbari coal-beds were recognized as typical of a separate horizon, under the name of *Karharbari beds or Karharbari group* (see Manual, Geology of India, 1879, Vol. I, pp. 112 *et seq.*), and I myself was enabled already in 1879 to publish a monograph on the Karharbari Flora, together with that of the Talchirs. In that work I have given at end also a list of the localities (respective shafts) whence the fossils were obtained; on pp. 38-39, the locality *Domahni* is noticed, from where there were fossils since 1871 (collected by Dr. Stoliczka) amongst the collections of the Survey. The fossils were:

> *Neuropteris valida*, Fstm.; fragment, top portion; (not figured).
> *Gangamopteris major*, Fstm.; (not figured).
> *Gangamopt. Comp. angustifolia*, McCoy; (not figured).
> *Sagenopteris (?) Stoliczkana*, Fstm., Pl. XIII, f. 4: (one specimen).
> *Glossozamites Stoliczkanus* Fstm., Pl. XX, f. 4, 5.
> *Noeggerathiopsis Hislopi*, Fstm., Pl. XIX, f. 3-5, (three leaves).
> *Voltzia heterophylla*, Bgt., Pl. XXIV, f. 4, (three branchlets, only one figured).

The Memoir contains, however, 27 plates (several double) with many figures, and *only* seven out of all were taken from specimens brought in 1871; *all others were collected by myself, by Mr. Whitty, and Mr. N. Miller.*

Report on the Oil-Fields *of* Twingoung *and* Beme, Burma; *by* FRITZ NOETLING, PH.D., *Palæontologist, Geological Survey of India.* (With one plate and a map.)

I.—GENERAL REMARKS.

1. *Position of the oil-fields.*—The oil-fields, generally but wrongly called oil-fields of Yenangyaung,[1] are situated at a distance of one mile and a half to east of that place near the villages of Twingoung[2] and Beme. Neither the names of these two villages nor the oil district is marked on the map of Burma (1 inch = 14 miles), but the position might be about where on the map the letter g of the word Yenan gyaung stands, *i.e.*, lat. 29° 21′ N., long. 94° 56′ E.

2. *Topography.*—The map does not give the correct features of the country; a hill range, like the one marked on it, does not exist in this part of the country. The country forms a tolerably level and flat plateàu, rising on the average to the height of 260 feet above the low level of the Irrawaddy at Yenangyaung; the highest point, the pagoda of Twingoung, being 313, the highest hill between Beme and Twingoung 293 feet above the same level. The whole country is intersected by numerous deep and narrow, irregular ravines, about which my map gives a very good idea. The whole country has obviously been originally one extended plateau, which has been eaten into by the action of the surface water, due to the composition of the strata forming the country and the irregularity of the rainfall during the year. The mechanical action of the water worked more in the direction of deepening and lengthening the water-courses than in widening them. By the eventual union of two opposite water-courses at their upper end into one a more or less extended piece of country was isolated, which took in time the form of a hill with flattened top and very steep slopes. On these latter of course the running water worked most energetically, notching them more or less.

Some parts of the country, especially the ferruginous, conglomeratic beds, resisted in a more energetic way the action of the surface water, which by washing away the surrounding softer strata modelled the harder ones to a kind of ridge, which was eventually eaten into a range of isolated hillocks or rocks. On the way from Yenangyaung to Beme or Kodaung we met with two of such ridges surmounting the surrounding plateau and running from S.S.E. to N.N.W. A closer examination proves that they are the remainders of a hard stratum of ferruginous conglomerate imbedded in the soft sandstones. The result of this process of the action of the water will be a country of rolling hills, with the tops generally on the same level, which are intersected by long, irregularly bent ravines, with steep, notched slopes. It is evident that a country like this is most difficult to cross, the roads being forced to accommodate themselves according to the run of the ravines. For instance, between Kodaung and Twingoung communication with carts is utterly impossible, the ravine between the two places preventing it. Therefore, a cart from Kodaung to Twingoung, a distance of 700 yards as the bird flies, had to go from either place *viâ* Yenangyaung, that is to say, a good day's march, in order to reach its destination.

[1] Yenangyaung = creek of oil.
[2] Twingoung = hill of wells.

3. *Geology of the oil-fields.*—The strata forming the country between the Irrawaddy and the Pin creek belong chiefly to the tertiary formation. For reasons which I shall give in detail elsewhere I feel inclined to believe that they represent the upper part of the tertiary formation, of no later age than Miocene. Likely enough they are of the same age as the Siwalik formation in India. As a matter of fact, the fossils I collected point to younger tertiary. Over the tertiary strata there is spread, but not continuously, a layer of ferruginous red gravel abounding in large pebbles of white quartzite and fossil wood, belonging to the diluvial formation.

Tertiary.

The strata mostly consist of laminated and clayey sands, sometimes a little indurated, so as to form soft sandstones. Some of the beds are highly calcareous and abound in concretionary masses of sandy limestone in the most varied shapes, many looking exceedingly like organic structures and frequently being considered by people to be such. In other beds there are nodular concretions of a very hard quartzitic sandstone, sometimes of an immense size, intercalated and arranged in irregular layers. There occur a few pebbly beds, and occasionally a layer of ferruginous sand or gravel cemented into rather a hard bed of ferruginous conglomerate. These layers of peroxide of iron are not unfrequently to be met with. Of inferior importance are clays and shaly clays.

The colour of the sandstones varies from white or a light yellowish tint in all stages up to a dark red and blue colour. The clays and sand-clays have a bluish grey tint. The minerals, occasionally imbedded, are gypsum, pyrites, coal. Nitrate of lime is formed abundantly on the surface of the rocks.

Detailed sections of the tertiary strata.

I shall now proceed to describe in detail the sections which I noticed in different localities of the oil-fields followed by a record of strata noticed in native wells sunk down at the time of my stay at the oil-fields.

No. 1.—Section in Messrs. Finlay, Fleming and Co.'s bore No. 1 at Kodaung,[1] No. 1 bore being 260 feet above the level of the Irrawaddy at low water (see Plate 1, No. 1):[2]

Thickness of strata in feet.		Total depth from the top.
	In descending order—	
5	1.—Grey stuff, soft, which grows harder and becomes yellow (evidently decomposed rock, forming the soil).	5
15	2.—Yellow stuff, which changes in red sand and clay, a little softer. (In the upper part soft, yellow sandstone, the same as met with at the end of No. 1, followed by a stratum of soft clayey red sandstone.)	20
10	3.—Red sand and clay, which changes to grey sand and clay. [The red sandstone is followed by strata of grey (better bluish-grey) colour consisting of alternate beds of soft sandstone and clay.]	30
20	4.—Grey sand and clay, very hard, oily smell. (The same strata as met with at the end of No. 3; a thin bed of harder sandstone has been noticed between 30 and 50 feet.)	50

[1] Kodaung = pigeon hill.

[2] I give the record of the strata as it was communicated to me by the Engineer in charge. Though correct on the whole, the record is highly unsatisfactory in detail. My own opinion about the strata is put within parentheses.

Thickness of strata in feet.		Total depth from the top.
50	5.—Grey sandy clay, partly hard. (The same remarks as under 4) . .	100
40	6.—Grey sandy clay, 2 feet of hard rock at 108 feet. (The strata are the same as before, that is to say, a frequent change of soft clayey and sandy beds, in which a band of hard sandstone is intercalated.)	140
42	7.—Grey sandy clay; 9 feet of hard rock at 150 feet. (The same as said under 6.)	142
33	8.—Grey sandy clay till 200 feet; it changes in grey clunch. (The same group of strata extends therefore to the depth of 200 feet, then by a sudden change the sandy beds disappear and are followed by a thick bed of bluish grey clunch.)	215
27	9.—Grey clunch; at the depth of 218 feet signs of oil; it changes at 220 feet in a green sand. (The clunch of No. 8 is in the upper part prevailing, but suddenly the strata change to a green sand. At 218 feet the first signs of oil are discovered. Apparently the real oil-bearing strata have now been tapped. The green colour is due to the oil with which the sand or soft sandstone is charged.)	242
38	10.—Fine sandy clay of greenish colour, changes to clay at 260 feet, 4 feet of hard white (?) rock and 1 foot more; at 270 feet oil becomes better as the well gets deeper. (These brief remarks contain a lot of information about the strata the bore is now standing in. Evidently there is the same sand or soft sandstone prevalent, but it is obvious that it frequently changes with thin beds of clay, the colour of which is not mentioned, but I have no doubt it is the same colour as that of the clunch No. 8, this is to say, rather a dark bluish grey. Besides the clay-beds occur beds of hard rock (sandstone?) of, I should prefer to say, bright greyish colour.)	280
14	11.—Green sandy shale; there still appears to be oil. (I cannot exactly understand the meaning of sandy shale. I suppose the sandstone gets more indurated, changing with laminæ of shale.)	294
6	12.—Uncertain, but very hard rock of sandy nature (evidently a bed of sandstone from the same kind as formerly has been met with (No. 10, &c.) has been found).	300
40	13.—Sandy rock of light green colour (the same soft sandstone charged with oil, but apparently this bed only contains a small quantity of oil).	340
25	4.—Light green sand, in thehigher strata oil, which remains now at a depth of 130 feet from the top. (Strata the same as before, but some are more richly charged with oil than others. The oil stands apparently under pressure so as to push it up to the depth of 130 feet from the top.)	365
25	15.—Gravelly formation, mixed with gravels, just a little gas. [This notice is highly vague as it is impossible to find out the meaning of "gravelly formation mixed with gravels." There might be a conglomerate (but of what kind?), a conglomeratic sandstone, or even a bed of gravel.]	390
15	16.—The same as before, sandy, of a light greenish colour. (The same as said before.)	405

It was not easy to classify these, sometimes rather indistinct notes, but I believe the following scheme will give a fairly good section of strata:—

Thickness of the single beds in feet.		Total depth from the top.
	In descending order—	
3—4	Decomposed rock forming the soil	3—4
12—14	Soft, yellow sandstone	16—18
11	Soft red sandstone, probably a thin stratum of light bluish clay is imbedded .	29

Thickness of the single beds in feet.		Total depth from the top.
79	Soft sandstone of bluish grey colour, thinly laminated, numerous beds of clay, sandy clay and sandstone alternating; occasionally thin beds of hard sandstone. The strata are feebly soaked with oil, up to 50 feet from the top.	108
2	Hard grey sandstone	110
40	Bluish grey sandstone, of the same quality as before mentioned . . .	150
9	Hard grey sandstone	159
41	Bluish grey sandstone, the same quality as before mentioned, but probably at its base the clayey beds grow thicker.	200
20	Blue stiff clay (clunch).	220
60	Fine soft sand of greenish colour, frequently alternating with thin beds of dark bluish clunch, a thicker bed of which has been found in an uncertain depth, the sandstone soaked with oil.	260
4	Hard grey sandstone	264
6	Soft sandstone of greenish colour soaked with oil	270
1	Hard grey sandstone	271
14	Rather hard sandstone of greenish colour alternating with beds of shale .	294
6	Hard grey (?) sandstone	300
65	Soft sandstone of light greenish colour, in beds, unequally charged with oil .	365
40	Conglomeratic (?) sandstone, or conglomerate of light greenish colour soaked with oil.	405

No. 2.—Section in the ravine between wells Nos. 5 and 118:—

In descending order—

	Ft.	In.
(*a*) Soft sandstone of reddish colour in thick beds	10	0
(*b*) Soft light blue clay	2	0
(*c*) Soft sandstone coloured dark red	15	0
(*d*) Soft clayey sandstone of blue colour in beds of a few inches thickness, alternating with thin beds of dark red sandstone. The base is formed by a bed of hard red sandstone of 3 to 4 inches thickness	10	0
(*e*) Numerous thin beds of bluish-grey micaceous sandstone, alternating very regularly with thin beds of blue clay	8	0
(*f*) Hard grey sandstone	0	4
(*g*) Sandstone like (*c*), but less regularly bedded	15	0
(*h*) Hard grey sandstone	1	6
(*i*) Sandstone like (*g*)	15	0
TOTAL .	75	10

No. 3.—Section in the eastern ravine:—

In descending order—

	Ft.	In.
(*a*) Soft, light yellow coloured, a little clayish, sandstone in thin beds. Occasionally thin plates of gypsum are imbedded	15	0
(*b*) Soft dark red coloured sandstone	2	0
(*c*) Soft white sandstone in thick beds	13	0
(*d*) Soft light blue clay	8	0
(*e*) Soft dark red coloured sandstone	9	0

(*f*) Soft light blue clay	5	0
(*g*) Soft light yellowish coloured sandstone in thick beds . .	15	0
(*h*) Numerous thin beds of bluish-grey sandstone, alternating with thin beds of blue clay	24	0
(*i*) Hard grey sandstone	0	4
(*j*) Soft bluish grey sandstone like (*g*)	9	0
TOTAL .	100	4

No. 4.—Well No. 75. The well is situated on the top of the hill, and had, at the time I examined it, just passed the depth of 160 feet. I was informed that at the depth of 160 feet a bed of a very hard rock gave a good deal of trouble in breaking. Large fragments of the said rock amongst the refuse proved to be a hard quartzitic sandstone of grey colour, which formed a bed of not less than 4 feet thickness. Below this bed a soft, rather coarse sandstone of a light greenish colour and a strong oily smell was found. Remaining several days under the influence of the sun the colour faded, clearly proving that it was solely due to the oil the sandstone was charged with. The sandstone then resulting was of light bluish-grey colour, consisting of rather coarse grains of milk or light blue coloured quartzite, mixed with grains of a black mineral the nature of which I could not ascertain. Small leaves of mica were not unfrequent. Breaking a larger lump, the centre still had the greenish colour, while the peripheral parts were of the colour just described.

No. 5.—Well No. 102. At the time I examined this well it had arrived at the depth of 151 feet. It was then standing in a coarse soft sandstone of greenish colour.

No. 6.—Well No. 150. The well had the depth of 265 feet and yielded 120 viss of oil a day. For some reason the owner started further digging, and the refuse brought out proved to be a dark blue clunch, which was superficially covered with oil, but did not contain oil itself.

No. 7.—Well No. 159. In depth of 183 feet, a soft green coloured sandstone was found, which alternated with thin layers of a dark blue coloured clay without oil.

No. 8.—Well No. 173. Notwithstanding the depth, 240 feet, this well yielded daily only 30 viss of oil. The strata at that depth consisted of rather a hard, thin-bedded sandstone of dark bluish-grey colour, alternating with thin layers of a blue clay. The refuse was superficially soaked with oil, but the interior proved to be without oil. It is obvious that the oil trickles out from a higher bed.

No. 9.—Well No. 174. After a careful inquiry the workmen stated that they met at 166 feet (100 attoung) depth with the hard grey sandstone, big lumps of which were among the refuse. When I visited this well it had reached the depth of 212 feet, the rock being a fine, thin-bedded sandstone of bluish-grey colour, sparsely alternating with beds of blue clay. The well yields a small quantity of oil which certainly does not ooze out from this bed.

No. 10.—Well No. 175. The well had reached the depth of 160 feet, and there a bed of a hard sandstone gave immense trouble to native workmen. To such an extent was this the case that work was several times given up, the men being unable to remove the obstacle without blasting. Above that bed the sandstone was softer and coarse, numerous imbedded quartzite pebbles rendering it somewhat conglomeratic while it was poorly soaked with oil.

No. 11.—Well No. 195. At 200 feet depth a soft, coarse sandstone of greenish colour.

No. 12.—Well No. 212. At 239 feet depth dark blue coloured stiff clunch; containing paper-thin layers of green sand imbedded.

No. 13.—Well No. 239. At a depth of 247 feet soft fine sandstone of green colour richly soaked with oil.

No. 14.—Well No. 242. The native workmen stated that at 117 feet depth they met with a hard grey sandstone; the well had now reached the depth of 150 feet. There the sandstone was soft, of light green colour, which after having been exposed for some time to the sun quickly changed into dark brown.

No. 15.—Well No. 266. It is stated that at 117 feet depth a bed of grey hard sandstone was found; the well is now at 130 feet; the strata consist of a soft, thin, laminated sandstone of bluish-grey colour alternating with thin beds of bluish-grey clay.

No. 16.—Well No. 278. The natives state that they met with two beds of hard grey sandstone, from which big lumps are amongst the refuse, at 133 and 183 feet depth. At present the well stands at 200 feet depth in soft green sandstone, poorly soaked with oil.

No. 17.—Well No. 298. The well had reached the depth of 156 feet; the strata consist of soft, coarse sandstone of light greenish colour in which a layer of 6-inch thickness of a fossil-bearing conglomerate is imbedded. The conglomerate consists of white and black quartzite pebbles, and rolled fragments of bones cemented by a soft clayish cement of greyish colour. Crystals of pyrites are frequent.

This conglomerate is highly interesting from the numerous fossils it contains. Unfortunately the larger specimens are all broken or deformed by the rolling, but smaller specimens are well preserved. I collected—

(1) a fragment of shinbone of a huge animal (*Elephas?*).
(2) a well-preserved tooth of a big carnivore.
(3) a tooth of a herbivorous animal (*Cervus?*)
(4) *Crocodilus sp.*, several teeth.
(5) *Turtle bones.*
(6) *Carcharias sp.*, many teeth.
(7) *Odontaspis sp.*, many teeth.
(8) *Myliobatis sp.*, teeth.
(9) *Teleostii gen. et sp. div.*, many fragments.
(10) *Gastropoda gen. div.*
(11) *Pecten sp.*
(12) *Arca sp.*
(13) *Cardium sp.*
(14) *Venus sp.*
(15) *Teredo sp.*
(16) *Corallium gen. div.*
(17) fossil wood frequently changed into coal.

No. 18.—Well No. 321. The well, which has now the depth of 253 feet, stands in coarse soft sandstone of green colour, fairly soaked with oil. According to native

statements, the beds of hard grey sandstone were met with at 100, 117, and 166 feet depth.

No. 19.—Well No. 328. At the depth of 225 feet a bed of blue stiff clunch containing thin layers of green sandstone. The strata above this bed consist of light green coloured, soft sandstone.

No. 20.—Beme Well No. 38. The well, which is only a few feet above the bottom of the ravine, had arrived at the depth of 145 feet; the strata consisted of a blue stiff clunch in which occasionally thin beds of green sandstone were imbedded.

I must add that in this record I only put down statements on strata actually brought out from the well at the time of my presence and examined by myself. I might have guessed about the strata formerly found from the nature of the refuse around the well, but being more or less speculative, I preferred to omit this part in the record as well as in the sketch. In special cases only, when after thorough inquiry I might feel convinced that at a certain depth a certain bed had been found, I put down a note of it in both record and table.

With the view of giving a more conspicuous summary of the details here mentioned I have compiled them on the annexed plate. In designing it I had of course the difference in the level of the wells to take into consideration, but being practically very small (all the wells here mentioned are situated on the top of the hill), I considered no harm would be done in neglecting it and in drawing the section of the wells, as being all on the same level. Besides, I should hardly have been able to state the exact difference in the level of the wells as I had only a small barometer for levelling, which, well adjusted as it otherwise proved to be, hardly admitted of noting differences in levels of less than 10 feet.

Groups into which the tertiary strata may be divided.

Although my observations have been few, still, when viewed together, they are sufficient to warrant certain conclusions being drawn relative to the series of superincumbent strata and oil-bearing beds. The record of strata so obtained might be considered in its details correct from 0 to 100 feet depth, fairly correct up to 220—225 feet, and doubtful in details, but correct as a whole in greater depths according to the better information I was able to gather.

In descending order we can distinguish four groups of strata:—

(*a*) *The upper group.*—Consisting chiefly of sandstones of brown and yellow colour followed by similar beds of dark red and yellowish white colour. The sandstones are soft, deposited in thin beds in the upper, in thick beds in the lower parts of the group. Gypsum in thin plates is not scarce in the upper brown sandstones; fossil wood in doubtful, highly decomposed logs in the lower sandstones. Interstratified are beds of light blue soft clay varying very much in thickness. The thickness of the whole of this group is about 20—30 feet in the centre of the field, but it rapidly increases in both directions towards west and east, for reasons which will be explained later on in section 5.

(*b*) *The second group.*—Consisting chiefly of bluish-grey sandstones and

clays alternating in innumerable beds very regularly in the upper less regularly in the lower parts. At the depths of 80 and 125 feet from the top (120 and 160 feet from the surface) occur beds of hard grey sandstone of sometimes more than 4 feet thickness. Concretions of hard nodules of sandstone in irregular layers are sometimes to be found as well as occasionally small fragments, and even small seams of coal, besides a small number of interesting fossils, being a mixture of terrestrial and marine animals of late tertiary age. The thickness of this group might be considered of not less than 170 feet. The lower part of this group is fairly soaked with oil which actually oozes out from the strata at numerous places in the ravines. Notwithstanding the rather considerable amount of oil with which the lower part is soaked, this group cannot be considered as the oil-bearing formation proper as is proved by the wells of less than 200 feet in depth, which never yield large quantities of oil. The strata were, apparently enough, originally not charged with oil. The oil they contain originated from deeper strata and rising by cracks gradually charged the soft sandstones. At the various outcrops of this group the oil may be seen leaking through to the surface, a circumstance which accounts for the original wells sunk by the natives.

(c) *The third group.*—Consists of a stiff clunch of dark blue colour, having imbedded in its lower part irregular thin beds of green sandstone. Thickness 20—25 feet.

The "blue clunch," as we may call this group, forms an extremely regular bed amongst the various strata composing the tertiary strata of Twingoung. There is not a single well in the two fields deeper than 200 feet which had not to break through this bed before reaching the oil-bearing strata proper. The blue clunch forms the boundary bed between the upper strata and the oil-bearing sandstone of which it forms a hermetical covering, thus preventing the oil from escaping. The blue clunch wherever it is found may be regarded as the first sign of the presence of the oil-bearing strata, which will be met with immediately underneath. Of course the depth in which the blue clunch might be found elsewhere depends upon local conditions, but within the limits of the Twingoung and Beme oil-fields it may be said that it will be generally found at *an average depth of 200 feet when the well is on the top of the hill and of 100 feet when in the ravine.*

(d) *The fourth group, or oil-bearing sandstone.*—The strata composing this group do not differ in any way from the constituents of the (b) group. They are more or less soft, coarse or fine micaceous sandstones, of bluish-grey colour, which is of course invariably changed into a more or less yellowish-green, according to the amount of oil the sandstone is saturated with. There are beds of hard sandstone and besides layers of greater or smaller thickness of blue clunch. In short, petrographically speaking, the (d) group is exactly the same as the (b) group, and these two, together with

the (*c*) group, belong to one geological system of strata; it is only from practical considerations that I have subdivided them. Unfortunately nearly all and everything is lacking on which to form a judgment regarding the constitution of this important complex of strata. The scanty data I was able to collect are by no means sufficient for the purpose. It is very likely that in the upper parts the (*d*) group forms a complex of beds of sandstone varying exceedingly in thickness, probably as well in vertical as in horizontal direction, which are separated by layers of blue clunch impenetrable to oil.

If I interpret in a correct way the data yielded by No. 1 bore of Messrs. Finlay, Fleming and Co., the separating clay beds thin out as the depth increases where the beds of sandstone grow thicker. The eminent importance of such a condition, if correct, will immediately be seen. Provided that the data above referred to are correct, it seems that from 300 up to the depth of 366 feet there is a bed of sandstone uninterrupted by any other beds, either clay or hard sandstone.

It further seems that from the depth of 366 feet downwards series of conglomerates or conglomeratic sandstones begin. Unfortunately I have not seen any samples of these strata, which the Managing Engineer called "gravelly formation," so I am only able to interpret his notes as a kind of conglomerate. But whether these strata are separated by beds of another constitution or whether they form an uninterrupted complex of coarse conglomerates I am not able to say.

This group is so far known to have a thickness of not less than 180—185 feet,[1] but I have no doubt that the thickness is a considerably larger one.

4. *Occurrence and origin of the oil.*—(*a*) *Occurrence of the oil.*—The (*d*) group is especially distinguished in containing a large amount of oil, and it must be considered as the oil-bearing strata proper. The oil is only to be found in soft *sandy* beds more or less richly soaked with oil, from which it slowly exfiltrates into the well or bore sunk in these beds. From the geological constitution of the strata I doubt the existence of natural reservoirs filled with oil and I never noticed the clayey beds or hard sandstones charged with oil. Therefore we have to consider the soft sandstones to be the valuable beds and accordingly to deduct from the total thickness the thickness of numerous beds of clay and hard sandstone in estimating the total thickness of the valuable oil-bearing sandstone.

(*b*) *Total thickness of the oil-bearing sandstone.*—I should think the total thickness of the useless strata is not exaggerated by estimating it at 50 feet; the present known thickness of the oil-bearing sandstone would therefore be not less than 130—135 feet. But there is more than one reason to believe that the oil is not equally diffused throughout the sandstone, that is to say, that the different beds are equally soaked with oil. On the contrary, there are several proofs that two beds of sandstone at different levels differ highly in the quantity of oil they

Difference in the production of wells of same and different depth and explanation.

[1] There is some uncertainty about the depth of bore No. 1 from which I got these data. The Engineer in charge told me at first the bore had reached the depth of 425 feet; afterwards he restricted his statements to 400—405 feet depth. According to measurements lately taken the bore has only the depth of 392 feet.

contain (see Section 3), and it is not necessary that a certain lower bed should be more richly charged with oil than an upper one. Not only do beds, different in level, differ in quantity of oil, but we also notice that wells of exactly the same depth and closely situated to each other differ highly in the production; in other words, that if at one place at a certain depth the sandstone is rich in oil, at another place close by at the same depth hardly any oil is found. The best instance are wells No. 253 and No. 244, which are only a few feet distant from each other, and yet well No. 244, which is even deeper than No. 253, yields only 50 viss per diem, while No. 253 yields 450 viss a day.

One should certainly think that the deeper well ought to have struck the beds rich in oil in sinking down, but it did not. How is this matter to be explained which puzzled everybody acquainted with the oil-fields?

There is only one solution of the problem. I stated above that in the upper parts of the (*d*) group a frequent change of beds of clay and sandstone must be supposed, and from samples I have seen it may be expected that the change is rather an irregular one; the same bed may rapidly swell at one place and likewise thin away, even perfectly die out, at another one close by. Two formerly thin beds may unite into a thick one by the disappearing of the separating medium, or a bed of clay may suddenly divide for a short distance, enclosing between the two branches a lenticular mass of sandstone which may be richly soaked with oil, while the sandstone above and below the clay is only poorly charged with oil. In Fig. 1 of plate, (*A*) well will by accident as it were strike the spot where the rich bed is enclosed, and will therefore yield a large quantity of oil, while (*B*) well, which is close by, only meets with poor sandstone. (*B*) well may be sunk to any depth, but it will never meet with the same beds supplying (*A*) well so extensively with oil.

As nearly all the native wells work the upper part of the (*d*) group, where geological conditions as described are prevalent, the large difference in production of wells of the same depth, and the fact that a well producing more oil than another one is less deep than the latter, is now easily explained.

Difficulty in stating the depth where the richest strata may be found.

It is obvious that under these circumstances no opinion can be formed as to the depth at which the richest beds are to be found. In fact none but the vaguest speculations could be formed. All we know at present is that the separating useless beds of clay diminish in number with the depth, so that the thickness of the valuable sandstone beds increases; but even this statement requires further confirmation. A bore of 400 feet in depth has accordingly more chance of reaching productive beds, promising a fair supply for years, than a bore of 250 feet, which might or might not instantaneously yield a great quantity of oil, but the duration of which could not be counted on because the deeper bore certainly drains the larger volume of sandstone.

Reasons why no high pressure of gas can be expected.

In Section 3 I have stated that, according to the data of No. 1 bore, the top of the (*d*) group has been met with at a depth of 220 feet, the mouth of the shaft being 260 feet above the level of the Irrawaddy at low water. The top of the (*d*) group is therefore 40 feet above the level of the Irrawaddy and not more than 120 feet below the bottom

of the ravine north of Kodaung. Conditions being nearly the same all over Twingoung and Beme oil-fields, as will be seen in Section 5, the highly important fact results that *the oil-bearing strata are extremely near to the surface*, and that in consequence no *high pressure of gas might be expected anywhere over the said area.* It will easily be understood that even if the oil-bearing strata were under high pressure elsewhere at a place where they are so near the surface, the pressure must rapidly decrease, owing to the intense escape of gas through cracks in the strata.

A small pressure yet existing.

There is still a small pressure proved by the experience of No. I bore at Kodaung. The oil there is said to have been pushed up to the depth of 130 feet from the surface; the top of the oil-bearing sandstone being 220 feet from the surface; the pressure is therefore high enough to push up the level of the oil through a height of 90 feet, supposing the oil to ooze out from the uppermost strata. This likely enough is not the case, but the oil originates, on the contrary, from deeper strata, and hence the pressure may be considered to be stronger than one sufficient only to push up the oil 90 feet above its level. The prospects for a high pressure at places where the oil-bearing strata are not so superficially situated, are therefore not so bad. Even flowing wells might be expected in places where the oil-bearing strata are of insufficient depth to prevent too extensive an escape of gas.

Origin of the oil.

I have no doubt that the oil-bearing sandstone is the oil-producing formation too, if not in its upper parts. I admit it is difficult to prove this statement at present owing to the very incomplete knowledge we have about the oil-bearing sandstone itself. But I may quote some facts. Samples of sandstone from greater depths are so richly soaked with oil that it is difficult to understand how the oil originating from lower strata was able to penetrate upper strata in such considerable amount and to soak them so intensely. Far more important, as supporting this theory, is the frequent occurrence of lumps of coal in the oil-bearing sandstone. I venture to think that by some chemical process, the nature of which is unknown, whether we call it dry distillation or decomposition, seams of coal formerly and partly still existing were changed into oil. Bores of greater depth are certain to give further and more exact information about this matter.

Physical and chemical qualities of the oil.

To examine the oil as regards both its physical and chemical qualities a well-assorted laboratory and special instruments are required, as examinations of this kind cannot be done in the field. I had to drop the matter, which is but of little importance, as a sufficient supply of samples for such an examination is easily to be got at any time and can be examined everywhere.

5. *Stratigraphical part.*—The study of the architecture of strata forming a certain tract is the foundation of every speculation based on it. From the facts we notice on the surface we may guess the features of the country underneath, for ever concealed to our eye, and, based on careful observations, conclusions so drawn may be very correct. The features of the country in the Yenangyaung district are extremely simple. In marching from the river towards the east on the road to Twingoung and from there to the Pin creek, we notice the following conditions of dip

and strike, of which the most important observations are shown in the subjoined table :—

No.	Locality.	Dipping.	Striking.
1	Bank of the Irrawaddy at Yenangyaung	35° S. W.	N. 40° E.
2	Road between Yenangyaung and Kodaung (foot path)	32° S. W.	N. 40° E.
3	Near Enausu	18° S. W.	N. 40° E.
4	East of Twingoung	13° N. E.	N. 40° E.
5	Near Myausu[1]	27° N. E.	N. 40° E.
6	Pin creek, near Naka-u	34° N. E.	N. 30° E.

I only mention the principal localities; the great number of intermediate places where I observed the two constituents of geological architecture are of no interest as they yield exactly the same data.

From the above-mentioned principal data we see that, by moving in a straight line from the Irrawaddy eastwards, the dipping of the strata suddenly turns from south-west to north-east; we notice at the same time that in leaving the river the angle of dipping gradually decreases, and with the reversion of the dipping gradually increases until it has reached its former amount near the Pin creek.

I designed on Plate 1 a section illustrating this architecture of the country; the heights had of course to be exaggerated at the scale of 1 : 6·6.

Anticline formed by the strata.

The strata form therefore an anticline, on the centre or top of which the oil-fields of Beme and Twingoung are situated. The axis of the anticline agrees with the striking, *i.e.*, No. 40° E. The centre of the anticline is situated between the villages of Twingoung and Enausu, and owing to the special structure of the anticline, the strata are here horizontal, or nearly horizontal, as may be seen in the ravine north of Kodaung. Leaving the centre the strata gradually begin to dip to either side. In the beginning the angle of dipping is only small; we notice angles of 5—8° in the ravine north of Kodaung, but dipping quickly increases. We already notice angles of 27° and 32° in the ravines bordering the oil-field; the angle increases later on only at a small rate up to 34° and 35°.

It is the characteristic feature of the anticline that in its centre, strata which are elsewhere far below, are brought near to the surface. At the same time we find in its centre the oldest strata, and removing from it in either direction are constantly meeting with younger strata, being exactly the same on both sides of the anticline. For instance, we meet at the banks of the Pin creek again with the same soft sands abounding in numberless concretionary masses of sandy limestone as we noticed on the bank of the Irrawaddy.

The special architecture of the country will now easily explain why just on that very spot the oil industry has developed. The mechanical action which produced the anticline resulted in bringing those strata extremely near to the surface, which would else be far down below the surface at the spot where we notice them now. By the action of the surface-water deep ravines were eaten in, which considerably

[1] Myausu = southern village.

reduced the distance from the surface to the oil-bearing strata, allowing the oil now to ooze out from the strata at many spots in the ravines where cracks or fissures afford it an easy road.

Shape of the oil-fields depends on the geological structure of the strata.

The same architecture of the country will also explain the quaint oblong shape of the oil district. The map shows that the oil district considered in the whole, as well as in single parts, forms an oblong with two very long and two very short sides. How is this shape, which is certainly not accidental, to be explained? The study of the architecture of the country will answer this question. I must mention beforehand that the Burmans are not able to dig wells of a greater depth than 310 feet. The section on the plate shows however that, in consequence of the dipping on each side, the oil-bearing strata at but a short distance from the centre of the anticline are far beyond the reach of Burmese art. Consequently the Burmans moved, one would almost say instinctively, on the top of the anticline, digging wells on each side as far as the dipping of the strata allowed them to do so.

The axis of the oil district Twingoung-Beme agrees therefore, or nearly agrees, with the axis of the anticline and the strike, and its longitudinal boundaries were dependent on the dipping of the strata.

I fail to understand why the Burmans never tried to sink wells on the area between the Twingoung and Beme oil-field, and why they never tried to extend the oil-fields further north or south. I suppose it is a good deal due to the tradition which taught them that if they dug a well within the boundaries of the before said oil-fields they would get oil, while elsewhere no oil was to be got. Probably the failures of wells sunk at many places, as, for instance, the old wells east of the Twingoung oil-field, confirmed their belief. So I was told that the Burmans foresaw an absolute failure of the bores at Kodaung and subsequently were highly astonished when they learnt that the bore yielded oil. On the other hand, there is certainly a good deal of superstition which prevents them from digging wells at certain places. When I pointed out a place south of the oil-fields of Beme to a Burman, and asked him why people did not sink wells on that spot, he had any amount of subterfuges explaining why it was impossible to dig a well, at this place, which he admitted to be a good one. Several men had already tried there to dig wells, but nobody had succeeded in doing so. But evidently he concealed the true reason of the dislike of digging a well at this place, and so I am inclined to believe that some superstition was the true reason preventing people from digging.

Depth of the oil-bearing strata some distance from the oil-fields.

The theory I have thus arrived at regarding the geological structure of the country gives the means of answering the highly important question as to where we shall meet with the oil-bearing strata—

(*a*) in ½ mile, or 1 mile, distance or any other distance in an eastern or western direction;

(*b*) in ½ mile, or 1 mile, or any other distance in a northern or southern direction;

from the line I fixed as axis of the anticline.

In answering question (*a*) we have to keep in mind that in moving in a line perpendicular to the axis of the anticline, *i.e.*, in the direction of the dipping, the vertical

depth from the surface of a certain stratum or bed in a given horizontal distance from a starting point is only dependent on the angle of dipping. In Section 5 I stated that the angle of dipping gradually increases with the distance from the centre up to 34° and 35° at the banks of the Pin creek or Irrawaddy. Taking 35° as basis of the calculation, the top of the (*b*) group would be found—

	Ft.
At ½ mile distance from the centre in	1,890
At 1 mile distance from the centre in	3,750

The top of the (*d*) group would be found—

At ½ mile distance from the centre in	2,080
At 1 mile distance from the centre in	3,940

The centre of the anticline being not a mathematical line, a certain allowance must of course be admitted as to the real and the supposed centre; a range of four chains might be considered a fair one. The probable mistake in the vertical distance might therefore be estimated 3·5 per cent. of the horizontal distance at 1 mile, 7 per cent. of the horizontal distance at ½ mile.

As bores of 3,000 feet afford under normal conditions no especial difficulties, a bore sunk at a distance of ½ mile from the centre could still drain 800—900 feet of the oil-bearing strata in a vertical direction. At a distance of 1 mile the difficulties would be considerably greater as regards the oil-bearing strata, which would not be reached under 4,000 feet deep.

Question (*c*) is easy to answer if one considers that the N.-S. direction nearly corresponds to the strike of the strata; therefore, in moving from the oil-fields in that direction, the depth in which the oil-bearing strata are to be found will be everywhere the same as it is at Twingoung and Beme as far as the tertiary strata extend in either direction.

II.—THE OIL-FIELD OF TWINGOUNG.

6. *Area of the Twingoung oil-field.*—The area on which between the villages of Twingoung and Enausu[1] the oil-wells are situated forms an oblong the length of which is nearly three times its breadth, being 50 chains and 15—20 chains respectively. Narrow deep nullas with steep slopes form the boundary lines. The S.E. side forms part of a ravine, which continuing westwards reaches the Irrawaddy north of the police station of Yenangyang; the opposite N. W. side is formed by a ravine, the continuation of which I did not examine. The S. W. side is formed by two ravines, which beginning near Enausu on the top of the plateau run in opposite directions towards S. S. E. and N. N. W., eventually joining the north and south ravine respectively. We notice the same conditions on the eastern side formed by two ravines, which, commencing close together at a point east of the village of Twingoung, carry the water away thence in opposite directions. As I have already mentioned in Section 1, this main ravine is notched and scored by smaller ones.

The superficial area of the Twingoung oil-field within the limits just described is some 90 acres. In this area are situated the whole of the productive oil-wells of

[1] Enausu = western village.

the Twingoung district. There are on the eastern and western sides a small number of wells, outside these limits, but not a single one is productive.

The western group consists of not more than four wells, Nos. 92 to 95, of which three have fallen into disuse; only No. 95 shows any signs of being worked, but I am sure that it does not happen very often.

The eastern group, situated on both the slopes of a ravine east from Twingoung, contains only ruined wells. I could not get any information whether these wells ever yielded oil, or whether they were given up as fruitless experiments in early stages of the digging. However, some of them are of a considerable depth. Being therefore quite unimportant, these two groups of wells may remain out of consideration. They only are of use as demonstrating the architecture of the country, as pointed out in Section 5. The oil-bearing strata at these two places are at such a depth that they are beyond the reach of Burmese digging.

Characteristics of the oil-fields.

The oil-fields of Twingoung afford a highly interesting and characteristic view. On every side a feverish unceasing industry is apparent, unaffected either by the scorching rays of the mid-day sun or the blackness of night. Devoid, however, of all system or method, the bountiful soil is robbed of its riches in an aimless fitful manner, without thought for the future, or with any object beyond the rapid achievement of a momentary success.

Here we notice a well just stopped in the very commencement of digging years ago; there an old well, probably disused for years, undergoing resuscitation. Why? I am sure even the man who works it does not know it himself. Very likely the well yielded in former times a large quantity of oil and he hopes now to tap again the rich vein which grants him a high rent without much trouble. Here we see a black soil so richly soaked with oil that it stands in small pools, while the worn-out cylinder of the cross-beam proves that the well is worked at high pressure and yields probably a fair quantity of oil, while close to it the rotten cross-beam, partly eaten by the ants, and the broken walls, show us the inevitable end; the walls of the well quietly slide down until a funnel-shaped hole results, partly hidden by quickly-growing plants, and constituting a serious peril to the stranger. Here a well which slacked in the production is cleaned and deepened, and there a new well is busily starting; everywhere work, but unreasonable, either overhasty or neglected work! The oil-wells are a striking instance of the Burman's love for gambling. He knows he will find oil at that place; his friend probably owns a well which yields 300 viss a day. Why should he not harvest the same crop? And so he starts digging as close as possible to his friend's well; but his work proves to be a failure, or his money runs short: at any rate the well is given up and quickly breaks down; if not, another one takes up the work with probably a better success.

7. *Number of the wells. Productive and unproductive wells.*—In making an exact record of the wells I had at first to design a map of the oil district and to put down on it the wells. Having no other instruments for this purpose but a prismatic compass, and having to depend on pacing for the distances, my map cannot be expected to be absolutely correct. But it is more than sufficient to illustrate this report, and having put down the features of the country as correctly as possible, it will not be difficult to identify any well.

With regard to the record I had to number the wells, and I considered a separate numbering of each oil-field preferable to a continuous numbering of the two fields.

In the Twingoung field I began with the wells of the southern ravine, and continuing westwards along the slope to the northern end of the western boundary I turned then back in a southern direction across the plateau, and on arrival at the southern ravine I again turned eastwards and followed the slope of the eastern ravine across the plateau near Twingoung, keeping as much as possible to the course of the ravine, finishing up near the village of Enausu.

In the Beme field numbering commenced at its northern corner and running thence along the slopes of the hill finished on the southern slope of the hill facing the Minling creek.

There exists an older numbering and which, if it could have been accepted, would have simplified matters, but such evident confusion existed in these numbers in addition to some being wanting that to do so was impossible. However, I always put down in the record the older numbers where I could ascertain them, and I am at least able to trace the course of the older numbers. Numbering commenced at the north-western corner of the Twingoung field on the slope and ran straight to the Beme field, including in one continual rotation the wells of the two fields. The general course of it will be seen from the table appended to the record, with the help of which it is easy enough to identify the older numbers corresponding to mine. There are unfortunately enough many gaps in the wheels, with which the wells were worked, of the labels bearing their former numbers and confusion often occurs, two wheels bearing the same number.

I was not able to ascertain the time when the wells were thus numbered. Some of the natives told me that it was done under the Burmese Government, others stated that it was done immediately after the annexation. However, the wooden labels on which the numbers are marked are so rotten in many cases that I should incline to the opinion that the numbering must have been done previously to 1886.

The total number of wells in the oil-fields of Twingoung amounts to 375. According to the older numbering there were 396 wells; at least No. 396 was the highest amongst the old numbers. The older and the more recent counting of the wells therefore agree very well, as the small difference of 21 wells is of no importance. I venture to think that my counting is the exacter of the two, as three repeated countings gave always the same result, and so I shall consider 375 as the real total number of wells in April 1888. And even if I should have actually overlooked some wells, they were certainly not productive wells, but old, disused ones, hidden by the vegetation. In any case the number accepted, whether it be 375 or 396, does not mean only "productive wells." It contains wells of all kinds, new and old ones, wells where digging is still going on, and wells where it has been stopped years ago.

Unproductive wells.

Amongst the 375 wells there are 166 (44·3 per cent.) which are utterly unproductive (U. P. W.); the greater portion have fallen in and will never be repaired; those in which digging had ceased at early stages of their existence are but few in number. Work might be again taken up later on, but at present they must rank amongst the unproductive.

The remainder, 209 (55·7 per cent.), we may call productive wells, but we have again to distinguish between wells from which oil is regularly drawn up and those from which it is only occasionally drawn. In those belonging to the latter category two causes may be at work, namely, either they are old and nearly exhausted, or they are new wells in which the work of digging is not yet completed, from which oil is only drawn when a small quantity has collected during a few days' cessation of work. Of the first class, *productive wells* (P. W.), there are 120 (32·0 per cent. of the total number); of the second class *scarcely productive wells* (S. P. W.), there are 89 (23·7 per cent. of the total number). Of the total of productive wells the P. W. would be 57·4 per cent., the S. P. W. 42·5 per cent. There could not be better illustrations of the meagre proportion of the Burmese oil industry than these few data. Of a total number of 375 existing, only 32 per cent., that is to say, hardly a third, supply the oil trade.

Productive wells.

8. *Depth of the wells.*—I considered it as one of the most important parts of my work to ascertain the depth of the wells, because several essential questions, as, for instance, whether the quantity of oil increases with the depth, might so be answered. I therefore carefully measured the depth of all wells as far as they were accessible. Wells the depth of which was not measured, as will be seen from column 4 of the record, were only old, disused wells, to measure the depth of which was of no sort of use. Besides my own measurements I inquired the depth of each well according to native statements (column 5 of the record). Comparing the two data I was able to judge of the trustworthiness of native statements. The difference between the two data I put down in column 6 of the record, and marked it with + if the native statement was larger than my own measuring, with — if smaller. Mostly both measurements agreed fairly, but in single cases I had to notice a large difference. In such cases I ascertained the depth by repeated measurements; my results may therefore be taken as reliable. The incorrectness of the native statements was certainly due in most cases to the ignorance of the labourers, who always considered an incorrect statement preferable to none at all.

The greatest depth reached by a Burmese well is 310 feet (No. 129), the next is No. 135 with 305 feet, but none of the others reach depths of more than 300 feet.

I measured the depth of 236 wells, that is to say, of all the productive wells, besides a small number of unproductive ones, and these I have divided into five classes according to their depth:—

Table No. 2.

Well.	Class.	Total number.	B. W.	S. P. W.	U. P. W.
Wells up to 150 feet depth . .	V	26	3	11	12
Wells up to 200 feet depth . .	IV	66	28	27	11
Wells up to 250 feet depth . .	III	111	66	41	4
Wells up to 300 feet depth . .	II	30	20	10	....
Wells of more than 300 feet depth .	I	3	...	...	...

In the above table the first and second columns show the class of depth; the 3rd the total number of wells in each class; the 4th, the number of productive; the

5th, that of scarcely productive; and the 6th, that of unproductive wells in each class.

The table is highly instructive in several respects. It shows that the total number of wells increases from the V to the III class, where the maximum is reached, and then in the II and I classes rapidly decreases. The bulk of the wells of the V class digging is not yet completed; they have not yet reached the oil-bearing strata, so they can hardly be expected to be productive, a supposition which is proved by the next three columns; but in a short time, as soon as the work of digging is finished, a good number of these wells will rank amongst the productive ones. The wells of the IV class have, with the exception of a few wells which were sunk in the ravines, not reached the oil-bearing sandstone; they only drain the lower parts of the (*c*) group. The greatest number of wells belongs to the III class; the wells stand in the upper part of the (*d*) group, but they hardly drain more than 30 feet of it. We notice in the II class not more than 30 wells, a rapid decrease after the 111 wells in the III class and still more rapid decrease in the I class.

There could hardly be a better illustration to prove the unreasonable style of Burmese working. Beyond 250 feet the difficulties of digging increased so greatly that they could hardly be vanquished. Only 33 wells out of a total of 209 wells could be sunk beyond that limit.

I pointed out in Section 3 that the (*d*) group, the oil-bearing sandstone, is known to have a thickness of at least 200 feet; therefore those wells which we have to consider as being the main oil-producers do not drain more than 30 feet of the upper and worst part of the oil-bearing sandstone, and only 33 wells drain the oil-bearing sandstone up to about 80 feet. To work to a greater depth is impossible for the Burmese style of working. Therefore all over the place where the Burmese wells are situated nearly 100 feet of oil-bearing sandstone remain untouched and its wealth of oil measuring millions of viss unraised.

9. *Production of oil.*—As the data given by former examiners relative to the production of oil differ considerably from one another, I paid special attention to this part of my work by collecting as many authentic data about it as possible. I tried to find out the total daily production of oil by inquiring of the owners or labourers working the wells, the daily yield of each well and summing up the data thus obtained.

Difficulty in getting exact data.

But matters proved more difficult than I expected for the following reasons:—

(1) The production, not being a regular one at present, depends on the demand. Hence it happens that for days the production of oil is nearly stopped. At another time, if there is demand for oil, the hardest working goes on. Keeping in mind what I pointed out in Section 4, it is therefore quite intelligible that after three days' rest, the production of the fourth day is higher than the daily average if worked for four consecutive days. Therefore the data regarding the daily production must be expected to differ, especially as there does not exist a written record about the production of a single well.

(2) It is highly difficult, if not impossible, to control data given by the natives, provided even that they do their best to tell the truth.

But for reasons easily intelligible a native will state the daily production of his well rather too low than too high.

Accordingly, my statements about the daily production of oil must be read in the light of the above-mentioned facts, and by summing up the single data, the total production at least may be expected to be lower than it is in fact.

I succeeded in getting data about the production of 144 wells, but the total number of productive wells being 209, those regarding 65 wells are wanting. This last fact will not however, in my opinion, affect in any sensible degree the general results obtained, as the bulk of these wells belong to that class from which oil is only drawn at greater or less intervals.

Productive and scarcely productive wells.

I divided in Section 7 the productive wells into two classes, namely,—

(*a*) wells yielding less than 20 viss per diem = S. P. W. = scarcely productive wells ;

(*b*) wells yielding from 20 viss upwards der diem = P. W. = productive wells.

Wells belonging to class (*a*) I do not consider as exercising any essential influence on the total daily production. Most of them prove by their rotten condition that they are not regularly worked, but that oil is occasionally drawn up only on account of the existence of the well. They are hardly worked oftener than once a month, some of them even only every two months, and, calculated per diem, the production would hardly reach the amount of 10 viss. I need not mention that any data collected regarding these wells cannot but be more or less unreliable.

There are 89 wells of this class, but I only succeeded in getting data regarding 26 of them; of the remainder 63 wells, I was unable to obtain any information. Of course the S. P. wells are to be found at all depths (Table No. 2, Section 8). The bulk of them might be considered as exhausted wells, *i.e.*, wells that have exhausted the possible draining area at a certain depth. Only very few belong to that class which in the process of digging have not reached the oil-bearing sandstone, but which daily yield a small quantity of oil.

The 26 wells have a daily total production of 206 viss, the daily average therefore being hardly 8 viss. Admitted the daily average per well being 10 viss, that is, about one of the small pots in use, the total production of the S. P. wells [class (*a*)] would therefore be 890 viss, say 1,000 viss.

Total production.

Of class (*b*), there are 120 wells which yield according to my enquiries 10,384 viss per diem, that is, a daily average of 86·5 viss per well. The daily total, therefore, would amount to 11,274 viss, say 12,000 viss, which we might consider as the present minimum daily production, as according to information otherwise obtained, the average daily total production amounts to 15,000 viss, recently even to 17,000 viss.

Daily average.

Taking the other two data as bases of the calculation, the daily average of the P. wells [class (*b*)] after deducting 1,000 viss for the S. P. wells [class (*a*)] would be—

	Viss.
(1) At the rate of 15,000 viss = ...	117
(2) At the rate of 17,000 viss = ...	133

We therefore might estimate the average daily yielding of a well [class(b)] at not less than 87 viss, but more probably as between 117 and 133 viss, estimations which will be fairly correct.

Taking the wells as a whole, *i.e.*, 209, the average yield per well per diem would be—

	Viss.
(1) At the rate of 12,000 viss = ...	57·4
(2) At the rate of 15,000 viss = ...	71·7
(3) At the rate of 17,000 viss = ...	81·3

The lowering influence of the S. P. wells is evident when compared with the data before mentioned, and it would be a great mistake to take these wells, which are hardly of any importance as regards the production of oil, into consideration. It further results that Oldham, in estimating the number of wells as correctly as possible, so far overestimated their average yield as to place it two or three times higher than it is in fact.

Relation between depth and quantity of oil.

In Section 8 I classified the wells in five classes according to depth. It is a matter of the highest importance to know whether there is any relation between quantity of production and depth. It will, therefore, be necessary to arrange the wells according to their depth, and to take the average production of each class as it is shown in the appended table :—

Table No. 3.

Depth.	Class.	Number of wells of each class.	Total daily production in viss.	Daily average per well in viss.
0—150 feet . . .	V	3	80	26
150—200 feet . . .	IV	28	1,857	66
200—250 feet . . .	III	66	5,802	88
250—300 feet . . .	II	20	2,290	115
300 feet and more . .	I	3	365	121

It is obvious that the lower strata of the oil-bearing formation produce more oil than the upper ones, a fact which the geological consideration that I adduced in Section 4 might have led us to expect. Of course it must be borne in mind that this rule does not mean that well (*a*), for instance, which is deeper than well (*b*), but less than well (*c*), must consequently yield more oil than well (*b*) and less than well (*c*). Such a conclusion would be quite wrong, as very likely exactly the contrary might occur as will be seen from the record in many instances. These average rates *only prove the fact that at a greater depth the strata as a whole are richer in oil;* therefore the same number of wells of say 250 feet depth will produce more oil than the same number of wells of only 200 feet depth. The truth of this rule, that the production is in direct proportion to the depth, is a fact of considerable importance in its bearing on the further development of the oil industry of the Twingoung oil-fields. Unfortunately the total absence of the necessary data precludes its being tested for depths greater than 300 feet.

The table above shows that the increase in the yield of oil between depths of 150 and 200 feet is rapid, amounting to 154 per cent. The next 50 feet show an increase of 33·3 per cent., the next 50 feet 30·6 per cent., and greater depths only 6 per cent.

The conclusion therefore might not be utterly wrong, that further increase of oil with that of depth might be expected, but assuredly at a lower rate than in the upper parts of the strata.

The highest daily production of a single well was 500 viss (well No. 253). There being no greater production at present, we can again divide them into three classes according to the daily yield of the wells:—

Rich and poor wells.

Table No. 4.

(I) Poor wells, yielding less than 20 viss per day		89
(II) Fairly rich wells—		
(*a*) from 20 to 100 viss = 74	}	105
(*b*) from 100 to 200 viss = 31	}	
(III) Rich wells—		
(*a*) from 200 to 300 viss = 10	}	15
(*c*) more than 300 viss = 5	}	
	TOTAL	209

It is obvious from this table how poor the native wells are. Wells yielding less than 100 viss a day are 163, or 77·9 per cent. of the whole number; of wells yielding more than 100, but less than 200, there are only 31, or 14·8 per cent.; and of wells yielding more than 200 viss, not more than 15 or 7·1 per cent.

Therefore in sinking a new well, the odds of obtaining a daily yield of more than 100 viss would be 1 to 5, of more than 200 viss 1 to 11.

There is another question to be answered which is of the highest importance as regards the future development of the oil-fields. It is this, *Is there any regularity in the decrease in the production of oil from a single well within a given space of time?*

Annual decrease of the production.

It is obvious that there must be a decrease in the production after a certain time; any mine will be exhausted in time, and likewise the wealth of the oil-bearing sandstone must similarly become exhausted, and the production necessarily diminish. But it is important to know whether the decrease is *a rapid irregular one* or *a regular gradual one*. It would hardly be worth while to start an extensive working of the oil-bearing strata with the prospects that a bore might for instance yield this year 500 viss, and the next year only 50 viss or *nil*.

I am sorry to say that I could get but very scanty data, by no means sufficient to answer the question in a satisfactory way, as it is difficult to say how far they are reliable.

These data are summarized in the appended table:—

Table No. 5.

Consecutive number of the well.	Depth in feet.	Present daily production in viss.	Former daily production in viss.	Time of former production in years.	Annual rate of decrease in viss.	Annual rate of decrease per cent.
21	201	9	200	5	38	19
25	235	80	200	4	30	15
41	215	140	190	1	50	26
51	203	200	800	15	40	5

Consecutive number of the well.	Depth in feet.	Present daily production in viss.	Former daily production in viss.	Time of former production in years.	Annual rate of decrease in viss.	Annual rate of decrease per cent.
81	245	140	180	2	40	22
84	263	90	300	2	105	35
103	183	150	260	6	18·3	7
126	263	100	200	10	10	5
129	310	160	180	1	20	11
138	260	60	80	1	20	25
195	200	50	200	8	18	9
253	233	450	1,000	4	137	13·7
295	251	270	1,000	4	182	18·2
314	196	120	160	1	40	25
			Beme.			
108	?	*Nil*	2,000	60	33·3	1·6
151	?	*Nil*	1,000	30	33·3	1·6

All the wells in the above table occur at the level of the (*d*) group, as according to the place where they have been started, a certain allowance in the height must be admitted. Provided the data are correct, it would appear that in the first year the decrease is a rapid one, amounting to 25 per cent. of the original quantity. If the figures in the case of No. 84 are correct, the decrease would be even higher still, namely, 35 per cent. Later on the decrease goes on more slowly. Within a space of four, five, and six years we notice an average yearly decrease of 19 per cent., 7 per cent.; within 10 to 15 years the average is 5 per cent. per year.

Therefore all I am at present able to say is that in the first two years a rapid decrease of the daily production will be noticed amounting to not less than 25 per cent.; later on the decrease goes on very slowly, so that after 10 or even 15 years' existence the yearly rate is not more than 5 per cent. of the original production. It may even become so small as hardly to be noticed for some time; at least so I understand the statements of natives, who absolutely deny any decrease in the production of numerous wells within recent years.

The statements about the two Beme wells I only mention as curiosities as I do not believe them to be correct, but the headman of Beme, whose statements I have reason to believe are fairly reliable, assured me that they are correct. I asked him no particulars regarding these two wells because they are at pre sent only funnel-shaped holes, but when we passed them, the headman volunteered the information as to their exceedingly rich production. No. 108 is said to be 80 years old, and has now been disused some 20 years; the life of the well therefore would appear to have been 60 years with an average yearly decrease of 1·6 per cent.

10. *Age of the wells.*—One should anticipate that the age of a single well would yield useful hints as regards the intricate matter I discussed in Section 9. This would certainly be the case, provided that the well remained all the time at the same depth at which digging ceased, and thus drained the same bed or beds of oil-bearing strata; but this is by no means the case, as the native at once commences to deepen the well if he sees any chance of success. The age of the well therefore means in plain English only the age of the shaft. Of course there are wells which have evidently remained for a good many years at the same depth, but sooner

or later their time will arrive for deepening. The highest age of any of the Twingoung wells is said to be 70 years, but the bulk of them are much younger. As a matter of fact the Twingoung wells are younger than the Beme wells; the first mentioned oil-field has as a whole been certainly later started than the Beme field.

11. *Digging of wells.*—As soon as a native has made up his mind where he is going to have a new well, the workmen, usually four in number, begin to dig a square shaft, the sides of which measure between 4 and 4½ feet.

Tools used for digging the wells and hauling up oil, &c.

Over the well a cross-beam supported on stanchions at either side is placed, and in the centre of this is a small wooden drum[1] or cylinder; the drum and its axis are made of a single piece of wood; the axis runs on coarse, naturally grown, fork-shaped supports. The leather rope used in hauling up the oil passes over the drum, and on it is fastened the workman who is going to be lowered down as well as the common earthenware pot called yenanoie[2] in which the oil is drawn up. If possible, the well is so placed that the men or women who are drawing up either the pot filled with oil or the workmen walk down an inclined plane along the slope of the hill.

The instruments used for digging are extremely simple and chiefly consist of a tool called *tayuwen*. The instrument, the shape of which is shown in the Fig. 2, Plate 1, is about 4½ feet in length; it consists of a wooden handle and an iron shoe; the handle is club-shaped, flattened on the top and deeply notched 6 inches below the top; a conical iron tube, which ends in a two-pointed edge, is fixed to it. In working, the man grasps with his two hands the wooden handle at a little above the iron shoe, and, leaning the notch against his shoulder, forces the tool into the ground with all his strength; he loosens small pieces of the rock, which are brought out in a basket from the bottom of the shaft. It is obvious that a tool such as this can only be used with success in soft strata, while hard ones are a nearly invincible obstacle.

Timber.

To support the walls timber is freely used, and the shaft is throughout lined with it. The timber consists of clumsy beams, corresponding in length to the breadth of the well, of 3 to 4 inches breadth and 1 inch in thickness. The beams are notched at both ends with the object of admitting of no movement after once being fixed. This wooden wall has considerable strength, but it has to be frequently repaired, and permanently to be kept under supervision lest it should give way. It may be mentioned here that every well wants permanently to be looked after: cleaning and repairing take a good deal of time if the well is to remain in good condition.

Digging the wells.

The lowering of the workmen is rather ingenious. The man sits on two slings formed of strong rope running between his legs and knotted over his left shoulder. To prevent sliding, a thin rope runs down from the knot across the breast underneath the right shoulder to the back, where it is fastened to the rope forming the slings; a second rope for the same purpose is fastened round the hips. On account of the explosive gas filling the shaft, no light can be taken down; the workman is therefore obliged to tie up his eyes previously to descending to enable him to see during the short time he is down in the well. Without this simple device, it would take more time to accustom his eyes

[1] Gyin. [2] Yenanoie = oil-pot.

to the dark than he is able to stay down. The gas, which renders breathing a difficult matter, prevents his staying below for any time. I made several notes regarding the time occupied in the descent, staying below, and the subsequent ascent, and give these observations in Table No. 6 (time in seconds).

Table No. 6.

	Well No. 228, depth 227 feet.	Well No. 262, depth 210 feet.		Well No. 278, depth 195 feet.	Well No. 321, depth 253 feet.	
		First observation.	Second observation.		First observation.	Second observation.
Descent	45	44	44	43	47	47
Ascent	80	91	89	62	121	120
Period below	280	257	180	118	60	89

Further observations are needless, these few data clearly demonstrating how disproportional to the profit gained is the amount of labour and money expended in the Burmese method of working. The time usefully spent is hardly 25 per cent. of the total working time. Of course the time of staying down depends to a considerable degree on the quantity of gas which is developed, and the physical strength of the labourer. A young man will stay longer than a weak, old one, and in cases where the development of gas is great, the stay must be shorter compared with one where gas is not so rapidly developed. However, I never saw even a young and strong man able to stay down longer than 290 seconds, which I consider to be the longest time a man may remain in a well without becoming unconscious.

It hardly needs mention that in the upper parts of the well, where the development of gas is *nil* or nearly *nil*, the workmen are not troubled by it, consequently remain down in the well for a longer time.

Natural difficulties limiting the depth of the wells.

From the facts I stated above, it is obvious that the digging of wells after the Burmese fashion is costly and takes a good deal of time owing to the primitive tools and the natural difficulties. It further results that with increasing depth, the difficulties increase tremendously until they become invincible, forming thus a natural limit of depth for Burmese wells. This limit is about 310 feet, but I noticed that the Burmans dislike to going deeper than 250 feet as is clear from Table 2, Section 8.

The drawing up of the oil is as primitive as everything else; the rope is fastened round the neck of the ball-shaped pot, and being lowered is allowed to fill by sinking in the oil below. The oil thus raised is poured into another pot of the same shape containing from 10 to 16 viss of oil, 12 of which are packed on each country cart.

12. *Wages paid for digging.*—The wages for digging a well are paid according to the depth on a scale which will be seen from Table 7:—

Table No. 7.

Depth in attaung.	Rupees per attaung.
From 0 to 80 attaungs	From R1-5-0 to R1-8-0.
From 80 to 90 attaungs	From R3-8-0 to R4-8-0.
From 90 to 100 attaungs	From R5-8-0 to R7.
From 101 per each additional attaung	From R10 to R20.

As a rule the digging is paid in the following way. According to previous agreement, for the first 80 attaungs R105 to R120 are paid; for the next 10 attaungs are paid R35—45; from 90 attaungs (150 feet) the price increases largely as for the next 10 attaungs between R55 and R70 are paid; generally from 100 attaungs (166 feet) digging is paid per attaung and varies according to the difficulty of the work, and the greater or less development of gas, from R10 to R20.

13. *Value and interest of oil-wells.*—Referring to the rates paid for digging in Section 12, it is not difficult to estimate the total expenses of a well.

Taking for instance a well of 250 feet depth, without any special difficulties, the expenses for digging would amount to R970. For timber and wages for the men serving as draught-horses, R500 would not be too high an estimate. The total expenses of this well would therefore amount to R1,470, say R1,500. I do not think that this estimate is too high. In special instances, the total expenses are considerably higher. Calculating the expenses of the deepest well, No. 129—

	R
The wages for digging would amount to	2,170
The expenses for timber and other items	750
TOTAL .	2,920

or R3,000.

I never succeeded in getting exact data as to the total expenses of a well from natives; either they did not want to tell me the truth or they did not know it themselves. Such data as I received were vague and often enough highly exaggerated, as a Burman once smilingly admitted when I told him that his statements were exceedingly exaggerated.

The estimates that I have given here have, however, been calculated on the basis of certain well-established facts, and so should preferentially be adopted in further investigations of this nature.

Admitting a rate of interest of 10 per cent. and the same for amortization, the total annual interest of a well of medium size (R1,500) would amount to R300. The expenses being between R2,000 and R3,000, an annual interest of R400—600 would be required, or a monthly revenue of at least R25—50 would be required to cover interest and amortization of the invested capital after ten years.

At present for 10 viss crude oil 4 annas are paid; therefore to cover interest and amortization a monthly production of 1,000—2,000 viss, or a minimum daily production of 33·3—66·6 viss is required.

From the data given in Section 9 it clearly results that even the lowest daily average of 57·4 viss would cover the interest on wells of R1,500 and R2,000 value, and would still yield a small surplus. A well, however, of the value of R3,000 would not be covered by such a production. We may, however, take it as pretty well certain that the number of wells at the rate of R3,000 is a very small one; and, on the other hand, we know the daily average of 57·4 viss is at the least a low estimate.

I stated that the probable daily average is between 87 and 133 viss, but 117 to 133 viss would probably be nearer the mark.

From these data it is obvious that an oil-well is a source of gold for its proprietor yielding him yearly a considerable revenue; and, considered as an investment of

capital, it pays as high an interest as almost any other mining industry. An instance will render this statement more conspicuous.

I estimated in Section 12 the capital invested in well No. 129 to be R3,000. It would be required to pay—

	Viss.
(1) Interest and amortization per month . . .	2,000
(2) Loss, breakage, holidays, 15 per cent. of the monthly production	720
(3) Wages and other necessary expenses, 15 per cent. of the mothly production	720
TOTAL .	3,440

The well has a daily production of 160 viss, or 4,800 viss per mensem. Deducting 3,440 viss as calculated above, there remain 1,360 viss as a net monthly revenue; they would sell for R34, which would mean a net interest of 13·6 per cent., and in the case that the owner of the well is the owner of the capital, a total interest of 23·6 per cent., with amortization of the invested capital after ten years. Certainly not a bad investment of capital, and one which would be still better supposing the invested capital lower and the production better.

14. *Proprietors of the wells.*—The bulk of the wells is owned by natives, but there are a few which were confiscated from the former private owners by the Burmese Kings and now belong to the British Government.

Examining these Government wells, the remarkable fact is to be noticed, that only a small number are productive; the rest are unproductive disused wells. This apparently strange fact is susceptible of easy explanation. Whenever one asks who the owner of a mined well is, the invariable answer is "the Government," as in the eyes of a Burman it seems only right as doing no one any harm to put down the ownership of an utterly useless hole to Government. Such few of the "productive wells" as are recognized as Government wells yield but very little oil.

III.—THE OIL-FIELD OF BEME.

15. *Topography.*—The outlines of the Beme oil-field are much less marked than those of the Twingoung field. The bulk of the wells is situated on the north and south slope of a hill east of the Beme village, the top of which rises to 250 feet above the level of the Irrawaddy. In general its slopes are less steep than those of the Twingoung oil-field, but deeply notched on the southern side, producing thus a number of sharp spurs. The two water-courses on either side of the hill run east and west, joining a somewhat larger one running north-east and south-west, which after a sharp turn north of Beme joins the creek coming down from the Minling hill which reaches the Irrawaddy south of the police station of Yenangyaung. There are two smaller groups of wells north and south of the main group.

As a whole the Beme oil-field covers an area of about 35 acres, and its length in a N. S. direction is something like 27 chains, its breadth 20 chains.

16. *Geology.*—I have nothing to add to the geological remarks in Section 3 as being pecular to the Beme field. There are the same strata and there is the same geological architecture. I will only describe the position of the oil-field with regard to the anticline. In the western part of the field, the strata show a dipping towards the south-west gradually increasing from 11° to 23.° The same bed of blue clay, which is noticed on the top of the main hill, is found on the opposite slope of the water-course only a few feet above the bottom of the ravine. The angle of dip gradually decreases towards east, and at a small distance beyond the upper end of the southern ravine the change in the direction of the dip towards the north-east is again noticed. The position of the oil-field is therefore exactly the same as that of the Twingoung oil-field, only that the wells of Beme are situated on the top and western side of the anticline.

17. *Number of wells.*—The number of wells is considerably smaller than that of Twingoung as there are on the whole not more than 151. Amongst these there are not more than 72 (47·6 per cent.) productive wells, and the rest 79 (52·3 per cent.) are unproductive old wells which are mostly mere holes.

Amongst the 72 productive wells, there are 50 or 33 per cent. of the total number of wells which yield more than 20 viss a day, and 22 or 14·6 per cent., the production of which is less than 20 viss per diem.

18. *Depth of the wells.*—The Beme wells are more favourably situated than the Twingoung wells; their depth in general is therefore smaller than that of the Twingoung wells, the deepest well being not more than 270 feet (wells Nos. 41 and 89). I measured the depth of 78 wells, half of them ranging amongst the V and IV classes,—a fact which is easy to understand if we keep in mind that on account of their situation on the slope the oil-bearing strata were earlier reached.

The appended table shows the wells classed according to depth and the number of productive, scarcely productive, and unproductive wells. We notice exactly the same facts as I stated in Section 8, namely, the greatest number of wells in the III class, and the increase of productive and decrease of unproductive wells in proportion to the depth.

Table No. 8.

Depth.	Class.	Total number.	P. W.	S. P. W.	U. P. W.
Up to 150 feet	V	23	8	9	6
Up to 200 feet	IV	12	5	7	...
Up to 250 feet	III	36	31	5	...
Up to 300 feet	II	7	6	1	...
More than 300 feet	I	...	...	...	...

19. *Production of oil.*—The oil-production of the Beme field is much smaller than that of the Twingoung field, being not more than 3,658 viss,—that is, exactly one-third of the total production of the oil-fields. Those wells yielding more than 20 viss a day are not above 50 in number with a total production of 3,437, which

means a daily average of 68·7 viss per well; the remaining 22, "scarcely productive" wells, yield not more than 221 viss per diem; the average is therefore not more than 10 viss. The total average of the 72 wells is therefore 50·8 viss per diem.

If the wells be arranged according to depth and the average calculated for every range, we find exactly the same fact proved as stated in Section 9, *i.e.*, the *increase of the quantity of oil in lower strata* notwithstanding the seeming exception that the wells of the III class give a smaller average than those of the IV class.

Table No. 9.

Depth.	Class.	Number of productive wells in each class.	Total daily production in viss.	Average daily production per well in viss.
Up to 150 feet	V	8	505	63
Up to 200 feet	IV	5	365	72
Up to 250 feet	III	31	2,080	70
Up to 300 feet	II	6	487	81
More than 300 feet	I	...	...	...

The Beme wells have a considerably smaller yield than the Twingoung wells; there is not a single well producing more than 165 viss per diem; and even wells producing more than 100 viss are scarce, there not being more than nine.

It is difficult to say whether the wells on the whole are really poorer, or whether this smaller production is only due to the age of the wells. I incline to the latter opinion being the more probable because all the wells are of considerable age, and because no decrease has been noticed for a long time in the bulk of the wells. The Beme wells have now arrived at a stage where the decrease in the production is a very small one and hardly perceptible in a few years.

The data regarding the decrease of the Beme wells are even more vague than those of the Twingoung wells. However there is no reason to doubt the truth of the conclusions arrived at in Section 9.

20. *Age of the wells.*—Passing through the records we notice that there are a good many wells which are said to have an age of 100 years and not a few too between 70 and 80 years of age. I do not know whether these data are reliable or not; they prove, however, that the Beme field is of great age and is certainly older than the Twingoung field.

21. *Proprietors of the wells.*—There are also some wells which are owned by the Government, the number of which amounts to 28; but of these only nine are productive wells, yeilding 261 viss per diem. All the other wells are owned by natives.

22. *Digging, wages, value of the wells.*—Conditions here are exactly the same as at the Twingoung fields, and are described under Sections 11, 12, and 13.

IV.—COMPARISON OF THE TWINGOUNG AND BEME OIL-FIELDS.

A comparison of the two oil-fields, not uninteresting in some ways, proves that as a whole the character of the two fields is exactly the same without any especially remarkable difference in either.

There are 526 wells in the whole oil-district, but only 281 (53·4 per cent.) of them produce oil, and of these some 170 (32·3 per cent.) account for nearly the total production of oil, their production being 92·5 per cent. of the whole.

These few data speak volumes. The entire oil industry is supplied by not more than, one-third of the existing wells. Two-thirds are either utterly unproductive or their production is so exceedingly small that it is not more than 7·5 per cent. of the whole. What a waste of labour!

According to my notes, the total daily production amounts to 14,932 viss, of which the Twingoung oil-field supplies two-thirds, the Beme oil-field one-third. For reasons I mentioned in Section 9 my calculations are probably below the mark; still they may be taken as fairly correct, or at least as showing the minimum daily production of the oil-fields.

If the other data regarding the production are correct, the production of the two fields would amount from 18,658 to 20,658 viss per diem. It is not uninteresting to notice the very equal conditions of the two oil-fields, which might of course be anticipated from the geological conditions. The productive wells of both the oil-fields amount to nearly the half of the existing wells, and the wells which may be considered as the really productive ones amount to almost exactly one-third of the whole number. In the Beme field the unproductive wells surpass a little the productive ones, which points obviously to the higher age of the Beme field.

In both the fields the share of the production of the P. W. is nearly the same, being 92·1 and 93·9 per cent. of the total production; but remarkably enough the average per well is considerably lower in the Beme field (68·7 viss per diem) than in the Twingoung field, where it is 86·5 viss per diem, which again points to the higher age of the Beme field. The S. P. W. have in both the fields the same daily average of 10 viss.

Regarding the depth, the distribution of the wells is exactly the same in both the fields as will be seen from Table 12.

The relation between quantity of oil and depth is explained in Table 13. There is no doubt that, notwithstanding the exception of the III class wells of the Beme field, which have a lower average than the IV class wells, in both fields an increase of the quantity of oil with the depth is proved.

It seems strange that the average of the V class wells of the the Beme field exceeds considerably the average of the same class of the Twingoung field. But this is easily explained if we keep in mind that most of the Beme V class wells, situated on the slope, are in fact equal to IV class wells of Twingoung,—that is to say, if both the wells had been commenced at the same level on the top of the hill, the V class Beme wells would range amongst wells of the IV class.

If we sum up the most striking features of the two oil-fields, we may thus characterize them in a few words:—

The Beme field is at the end of its production, which has been in the past.

The Twingoung field is at the height of its production with a prospect of a small increase in the future.

Table No. 10.

Showing the number of Productive and Unproductive Wells in the Oil-fields of Twingoung and Beme.

		Unproductive wells.		Productive wells.		Wells producing more than 20 viss per diem.			Wells producing less than 20 viss per diem.		
	Total number of wells.	Number.	In per cent. of the total number.	Number.	In per cent. of the total number.	Number.	In per cent. of the total number.	In per cent. of the productive wells.	Number.	In per cent. of the total number.	In per cent. of the productive wells.
Twingoung .	375	166	44·3	209	55·7	120	32	57·4	89	2 ·7	42·6
Beme . .	151	79	52·3	72	47·6	50	33	69·5	22	14·6	30·5
Total of the two oil-fields	526	245	46·5	281	53·4	170	32·3	60·5	111	21·1	39·5

Table No. 11.

Showing the daily production of Oil of the Oil-fields of Twingoung and Beme.

	Daily production of oil in viss at 3·65 lbs.								Average daily production per well in viss at 3·65 lbs.		
	Total.		Of productive wells.			Of scarcely productive wells.					
	Viss.	In per cent. of the total number.	Viss.	In per cent. of the total number.	In per cent of the special number.	Viss.	In per cent. of the total number.	In per cent. of the special number.	Total average of all the productive wells.	Average of the productive wells.	Average of scarcely productive wells.
Twingoung .	11,274	75·5	10,384	69·5	92·1	890	6·	7·9	53·4	86·5	10
Beme . .	3,658	24·5	3,437	23·0	93·9	221	1·5	6·1	50·8	68·7	10
Total of the two oil-fields.	14,932	100·0	13,821	92·5	...	1,111	7·5	...	53·1	81·3	10

Table No. 12.

Showing the Wells of Twingoung and Beme arranged according to their Depth.

Depth.	Class.	TOTAL.		PRODUCTIVE WELLS.		SCARCELY PRODUCTIVE WELLS.		UNPRODUCTIVE WELLS.	
		Twingoung.	Beme.	Twingoung.	Beme.	Twingoung.	Beme.	Twingoung.	Beme.
Up to 150 feet	V	26	23	3	8	11	9	12	6
Up to 200 feet	IV	66	12	28	5	27	7	11	...
Up to 250 feet	III	111	36	66	31	41	5	4	...
Up to 300 feet	II	30	7	20	6	10	1	...	...
More than 300 feet	I	3	...	3	...	...	...	...	...

Table No. 13.

Showing the increase of Oil with the Depth at the Twingoung and Beme Oil-fields.

Depth.	Class.	NUMBER OF PRODUCTIVE WELLS.		TOTAL DAILY PRODUCTION OF THESE WELLS.		DAILY AVERAGE PER WELL.	
		Twingoung.	Beme.	Twingoung.	Beme.	Twingoung.	Beme.
Up to 150 feet	V	3	8	80	505	26	63
Up to 200 feet	IV	28	5	1,857	365	66	72
Up to 250 feet	III	66	31	5,802	2,080	88	70
Up to 300 feet	II	20	6	2,290	487	115	81
More than 300 feet	I	3	...	365	...	121	...

V.—FUTURE PROSPECTS OF THE OIL COUNTRY.

Before speculating on the future of the oil country in the Yenangyoung district it will be useful to discuss the future of the Burmese oil-fields.

This can be done in a few words as most of what will be said will be found in former paragraphs.

The future of the oil-fields depends on the style of working and on geological conditions. As I pointed out in Section 11, a depth of 310 feet means the limit beyond which Burmese workmanship cannot go.

As the geological conditions only admit of a small area being worked by Burmese labour, and as this limited space is now pretty well filled up with wells, leaving but little more for new ones, the future can easily be foreseen.

As soon as all the wells now in progress or that can be dug reach the depth of 310 feet the Burmese oil-industry must inevitably come to an end. But it is difficult

even to guess the number of years when the Burmese oil-industry will belong to the past. This depends mainly on the greater or less intensity with which the oil-field is worked. If there is a large demand for oil, which forces the Burmans to increase the depth of the wells to supply the demand, the end will rapidly arrive; if the deepening of the wells proceeds slower, the existence of the Burmese oil-industry will be prolonged. According to the way the working of the oil-fields is going on at present there will be a small increase of the production for the next years; it will then remain steady for a time, after which it will commence to fall.

While abstaining from any attempt to indicate precisely the exact number of years during which the Burmese oil-industry will continue to exist, still the various facts and data which I have collected warrant the conclusion that it can be only very short-lived.

The future, as I have depicted it, of the oil industry of Burma presents a somewhat dismal picture, and it would be still more so were European energy and enterprize not at hand to rescue it.

Relations between area and production.

Before I discuss the prospects of a European management of the Burmese oil-fields it is necessary to consider the relations between area and production, *i.e.*, to know (1) how many viss per acre and day the oil district can possibly yield, and (2) how many square feet of ground, or how many cubic feet of oil-bearing strata, are necessary to yield a certain amount of oil per diem. I base my calculations on the present daily average production of 12,000—17,000 viss (12,000 viss as the minimum production of the Twingoung field and 17,000 as the maximum present average of the district).

The Twingoung oil-field covers, according to a careful calculation, an area of 90 acres; the daily production per acre would therefore amount to 133—188 viss.

This area is drained by 209 wells, of which only 120 are considered to be real oil-producers. Taking this number, a single well would drain an area of 0·75 acre; we might also say on nearly every three-fourths of an acre there are two wells, but only one of which produces oil.

Calculating from the data at hand regarding 141 wells, each well drains in the average 42 feet thickness of the oil-bearing sandstone; therefore a well which yields 133 viss per diem drains a volume of 1,372,140 (1½ millions) cubic feet of oil-bearing sandstone, provided that the sandstone is uniformly charged with oil.

On the basis of this calculation a well which yields 100 viss a day drains 1,031,684 cubic feet. As from the Burmese method of working only a relatively small portion of this volume can be referred to height, it is evident that the Burmese well needs for its supply a large horizontal area. Supposing the owner of the well is able to work 100 feet thickness of the oil-bearing strata, I estimate the smallest area necessary for a well yielding 100 viss a day to be one-fourth of an acre. According to this supposition the area of the Twingoung oil-field could supply 360 wells at the daily rate of 100 viss. But as it is not very likely that each well will drain 100 feet oil-bearing sandstone (only three wells do so in fact), we assume this area would supply only half the estimated number of wells, namely, 180, yielding 100 viss per diem. The daily production would therefore amount to 18,000 viss, which comes so near to the stated production of 17,000 viss that in future only a small increase in production from native wells is to be expected.

It would not be difficult to calculate the probable further duration of the wells in years if the quantity of oil contained in one cubic foot of oil-bearing sandstone were known. Unfortunately, however, I can only state that the sandstone is charged with oil, but what the relative proportions of the oil and sandstone are in a cubic foot I am unable to say. To ascertain this would require years of the most careful observation. In this respect one is much worse situated than in the case of, say, a coal seam or a galena vein, where the volume of the existing mineral can be calculated fairly correctly, and once the yearly production is known, the number of years the mine will last is simply a matter of division.

The evil effects attendant on the unmethodical and irrational mode of working the oil-bearing strata adopted by the Burmese are thus evident. Their inability to drain any great thickness causes much valuable surface to be lost, and the oil-field yields less than it should do. The millions and millions of viss contained in the second hundred feet are thus irretrievably lost within the area of the present oil-fields.

In the case of European enterprize these hindrances to Burmese labour would not exist. Nowadays machinery is so perfect that the deepest bores can be sunk without any difficulty. A European bore would therefore drain probably the whole thickness of the oil-bearing strata with the following advantages:—

(1) the oil-bearing strata could be tapped by a greater number of bores;
(2) the production of each bore would probably be higher than 100 viss because we know that the quantity of oil increases with the depth;
(3) the supply would likely be a very steady one, less liable to change.

Working the oil-fields after European style would therefore considerably increase the production of oil without damage to the field. I have no doubt that the production of the Twingoung field might easily be raised up to 50,000 viss or more per diem if regular boring were substituted for the present wells. European bores would infuse new life into the present exhausted Beme fields.

An estimate of the probable minimum production of that small area between the two oil-fields on the map between squares Nos. 10 and 19, where Finlay, Fleming and Co. have started boring, will not be uninteresting. Taking only that area into consideration, which would fall within the limits of the Twingoung field if traced across this country, the area might be estimated at about 65 acres. Two bores per acre would certainly yield 500 viss per diem if sunk to 400 feet depth; the total daily production would therefore amount to 32,500 viss.

If we consider the rate of 500 viss per acre as the minimum production of a bore, one square mile would thus produce 320,000 viss per diem. The lease of Messrs. Finlay, Fleming and Co. reaches to within 4 miles of the boundaries of the two oil-fields. For reasons pointed out in Section 5, only 1 mile east or west can be considered as valuable ground. There would therefore be 16 square miles of highly valuable ground which would produce at least half a million of viss per diem, and I have not the slightest doubt that this quantity would be surpassed.

Technical difficulties in working the oil-fields.

There is only one difficulty in working the oil-bearing strata to any extent, and this is that, in consequence of the very small amount of pressure that exists, pumping will have to be resorted to in order to raise the oil. This fact will considerably limit the powers of production of each individual bore as pumping cannot be continuous,

intervals being necessary to allow of the oil exfiltrating again. The production is therefore completely dependent on the number of bores, and to work an oil district extensively would require a large number of wells. However, this is a technical matter, and once the necessary apparatus for boring is purchased the sinking of even a great number of bores would not be expensive. Should flowing wells by chance be tapped, the conditions would be totally altered and that too in a highly favourable direction.

Flowing wells.

My own opinion is that such wells will be found, if borings are carried out far enough away from the centre of the anticline to reach the oil-bearing strata at a sufficient depth to stop the gas escaping. It is only repeated experiments, however, that can prove their existence. The risk of boring at a fair distance from the centre of the anticline must be run. The result may of course prove either success or failure, but my own opinion is that success is the more probable of the two. Our knowledge regarding the composition of the oil-bearing group is at present still too limited to admit of a decisive judgment being given in this very important matter.

On the whole there is every reason to believe that the oil industry will develop in the future and will rank amongst the important mineral industries of Burma. Wild ideas about beating or competing with American or Russian oil cannot be too strongly deprecated as being only too likely to prove utterly illusory. The oil-fields, if worked rationally and methodically, will pay well enough, and if in future there should be found flowing wells, equal in production to American ones, so much the better for the Burmese oil-industry.

Summary.

1. The oil-bearing strata in the Yenangyaung division belong to the upper tertiary formation.

2. The oil-bearing strata chiefly consist of a fine soft sandstone of bluish-grey colour which is more or less soaked with oil, changing the colour of the sandstone into a yellowish green, but no data can be given as to the quantity of oil contained in 1 cubic foot of sandstone.

3. So far the oil-bearing strata are known to have a thickness of 200 feet, but there is no doubt that they are considerably thicker.

4. The oil-bearing strata are deposited in beds varying with the quantity of oil contained, separated, especially in the upper parts, by layers containing no oil.

5. The quantity of oil contained in the oil-bearing strata increases with the depth.

6. A bed of blue stiff clay of 20—25 feet thickness is invariably superimposed on the oil-bearing sandstone.

7. The oil-bearing sandstone is found very near the surface, its depth being not more than about 220 feet from the top of the plateau and 120 feet from the bottom of the ravines.

8. Owing to their superficial position no high pressure can be expected within the limits of the oil-fields.

9. The strata form an anticline, the strike of which is N. 40 E., with a maximum dip of 35° towards S. W. and N. E.

10. The oil-fields of Twingoung and Beme are situated on the top of the anticline.

11. The Twingoung oil-field covers an area of about 90 acres, its length being about 50 chains, its breadth between 15 and 20 chains.

12. There are 375 wells in the Twingoung field, of which 166 are totally unproductive.

13. Of the 209 wells which yield oil only 120 produce more than 20 viss a day.

14. The maximum produced by a single well is 500 viss a day; the bulk of the wells produce between 20—100 viss.

15. The total daily production amounts, according to my inquiries, to 12,000 viss, according to other statements from 15,000—17,000 viss per diem.

16. The daily average of a productive well ranges from 86·5 to 133 viss.

17. At present no exact data can be given about the yearly rate of decrease in the production of a well.

18. The wells are rather shallow; the deepest does not exceed 310 feet.

19. The Burmese wells yield a high interest, ranging from 23·6 per cent. upwards, with amortization of the invested capital after ten years.

20. The Beme field only covers 35 acres, its length being 27 chains, its breadth 20 chains.

21. There are 151 wells in the Beme field, of which 79 are totally unproductive.

22. Of the 72 productive wells only 50 produce more than 20 viss per diem.

23. The maximum production of a single well is not more than 165 viss.

24. The total daily production amounts, according to my enquiries, to 3,658 viss.

25. The daily average of a productive well amounts to 68·7 viss.

26. The wells are equally shallow, the deepest being not more than 270 feet.

27. The total number of wells in the two oil-fields is 526, of which 281 yield oil, but only 170 yield more than 20 viss per diem.

28. The total daily production of the two fields ranges from 14,932 to 20,658 viss.

29. The daily average production of one of the 170 productive wells amounts from 81·3 to 133 viss.

30. The Twingoung oil-field is at present at the zenith of its production, but still a small increase may be expected for the next few years.

31. The Beme wells have nearly extracted the oil existing in the oil-bearing sandstone and a decrease of production is to be expected.

32. The oil-fields, as worked by natives, have only a limited life; the oil industry could not be developed to a greater extent than it is at present.

33. As worked by natives only a small part of the oil-bearing sandstone is touched, for the greater part remaining untouched.

34. If worked according to European style, by bores, they are capable of a considerable development in the future.

RECORD OF THE WELLS OF THE OIL-FIELDS OF TWINGOUNG AND BEME.

I.—Record of the wells of the Twingoung oil-field.
II.—Record of the wells of the Beme oil-field.

Explanation.

Column 3 refers to the map.

In columns 4 and 5, *n. m.* means not measured.

Column 6.—The difference is marked with + if the native statement of the depth (column 5) has been found to exceed my measuring; — if the opposite case.

Column 9.—T. W. means twinza wells. G. W. means Government wells.

TWINGOUNG.

Key to find from a given old Burmese number the consecutive number given by me to the wells of Twingoung.

Remarks.—Burmese numbers in Roman: 1, &c.
Consecutive numbers in *Italics*: *1*, &c.

Burmese No.	Consecutive No.	Burmese No.	Consecutive No.	Burmese No.	Consecutive No.
1	...	55	...	109	*300*
2	...	56	*190*	110	...
3	...	57	*191*	111	*293*
4	...	58	*192*	112	*275*
5	*217*	59	*196*	113	*276*
6	...	60	*203*	114	...
7	*213*	61	*205*	115	...
8	...	62	...	116	*281*
9	...	63	*264*	117	...
10	*227*	64	...	118	...
11	...	65	*261*	119	...
12	*224*	66	...	120	*286*
13	...	67	...	121	*287*
14	*214*	68	...	122	...
15	...	69	*361*	123	*290*
16	*212*	70	*241*	124	...
17	*213* (?)	71	*237*	125	*292*
18	...	72	...	126	*294*
19	...	73	...	127	...
20	*181*	74	*249*	128	...
21	...	75	*247*	129	*298*
22	...	76	*246*	130	...
23	*194*	77	*251*	131	...
24	...	78	*259*	132	...
25	...	79	*269*	133	*302*
26	...	80	...	134	...
27	...	81	*266*	135	...
28	...	82	...	136	*308*
29	*253*	83	*1[illegible]9*	137	...
30	*244*	84	...	138	...
31	...	85	*201*	139	...
32	...	86	...	140	...
33	...	87	...	141	...
34	*230*	88	...	142	*309*
35	*231*	89	...	143	*311*
36	*234*	90	*174*	144	...
37	*235*	91	*188*	145	*354*
38		92	...	146	*314*
39	*232*	93	...	147	*315*
40	*238*	94	*280*	148	...
41	*240*	95	*278*	149	...
42	*245*	96	...	150	*323*
43	*242*	97	...	151	*318*
44	...	98	*273*	152	*322*
45	*262*	99	...	153	*324*
46	...	100	*270*	154	...
47	...	101	*271*	155	*320*
48	...	102	...	156	...
49	...	103	*256*	157	*325*
50	*195*	104	*248*	158	...
51	*193*	105	*305*	159	*317*
52	...	106	...	160	*328*
53	*179*	107	...	161	...
54	...	108	*257*	162	...

Key to find from a given old Burmese number the consecutive number given by me to the wells of Twingoung—continued.

Remarks.—Burmese numbers in Roman: 1, &c.
Consecutive numbers in *Italics*: *1*, &c.

Burmese No.	Consecutive No.	Burmese No.	Consecutive No.	Burmese No.	Consecutive No.
163	...	217	...	271	...
164	*289*	218	...	272	...
165	...	219	...	273	*103*
166	*331*	220	...	274	*104*
167	*330*	221	...	275	*144*
168	*332*	222	...	276	*145*
169	...	223	...	277	*143*
170	*336*	224	...	278	*136*
171	*338*	225	...	279	*135*
172	...	226	*156*	280	*134*
173	...	227	*153*	281	*133*
174	...	228	*159*	282	*131*
175	*345*	229	...	283	...
176	...	230	*158*	284	...
177	*350*	231	...	285	*129*
178	...	232	*149*	286	*128*
179	*351*	233	*148*	287	...
180	...	234	*147*	288	...
181	...	235	*141*	289	...
182	...	236	...	290	*106*
183	*346*	237	...	291	...
184	*344*	238	*139*	292	*76*
185	*347*	239	*137*	293	*77*
186	...	240	*142*	294	...
187	*334*	241	...	295	*73*
188	*333*	242	*150*	296	...
189	...	243	...	297	...
190	...	244	*101*	298	...
191	*161*	245	...	299	*75*
192	...	246	...	300	*69*
193	...	247	*99*	301	*70*
194	...	248	...	302	...
195	*162*	249	...	303	...
196	...	250	...	304	...
197	...	251	...	305	*94*
198	*170*	252	...	306	...
199	*171*	253	...	307	*123*
200	*168*	254	...	308	...
201	...	255	*85*	309	*126*
202	...	256	...	310	*125*
203	...	257	*88*	311	*122*
204	...	258	*87*	312	*113*
205	...	259	...	313	*120*
206	...	260	*89*	314	*121*
207	...	261	...	315	*110*
208	...	262	...	316	*109*
209	...	263	*92*	317	*22*
210	...	264	*95*	318	*111*
211	...	265	...	319	*65*
212	...	266	...	320	*29*
213	...	267	...	321	*30*
214	...	268	...	322	*64*
215	...	269	*81*	323	*63*
216	...	270	*80*	324	...

Key to find from a given old Burmese number the consecutive number given by me to the wells of Twingoung—concluded.

Remarks.—Burmese numbers in Roman: 1, &c.
Consecutive numbers in *Italics*: *1*, &c.

Burmese No.	Consecutive No.	Burmese No.	Consecutive No.	Burmese No.	Consecutive No.
325	...	349	*55*	373	*11*
326	*60*	350	...	374	*12*
327	...	351	*39*	375	...
328	...	352	*54*	376	*40*
329	...	353	...	377	...
330	...	354	...	378	...
331	...	355	...	379	*15*
332	*61*	356	...	380	...
333	...	357	*57*	381	...
334	...	358	...	382	*20*
335	*31*	359	...	383	*42*
336	*32*	360	*118*	384	...
337	...	361	...	385	...
338	...	362	...	386	...
339	...	363	...	387	...
340	*18*	364	...	388	*45*
341	*19*	365	...	389	*46*
342	...	366	*5*	390	*47*
343	...	367	...	391	...
344	...	368	...	392	*52*
345	*26*	369	...	393	...
346	...	370	*9*	394	*50*
347	*33*	371	*10*	395	*53*
348	...	372	...	396	*51*

I.—Record of the Wells of the Oil-field of Twingoung.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in at'aungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
1	?	9 D.	155	90	...	15	Once a month	T. W.	More than 10 years.	Decrease in yield of oil has not been noticed within the last 10 years.
2	?	9 D.	185	120	—15	140	Daily	T. W.	?	
3	?	9 D.	180	120	—20	60	Every 10 days	T. W.	?	
4	?	10 D.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
5	366	10 D.	208	132	—12	32	Daily	T. W.	?	
6	?	10 D.	243	140	+10	40	Daily	T. W.	?	
7	369	10 D.	167	...	...	..	......	T. W.	?	} Old well, broken down, yields no oil.
8	?	10 D.	...	...	...	...	......	T. W.	?	
9	370	10 D.	248	150	— 2	200	Daily	T. W.	More than 9 years.	Decrease in yield of oil has not been noticed within the last nine years.
10	371	10 D.	220	...	...	...	......	T. W.	?	This well yields at present no oil; the owner tries to get oil in a greater depth, so digging is going on, but has been stopped since six weeks.
11	373	10 D.	206	130	—10	120	Daily	T. W.	?	
12	374	10 D.	190	151	— 1	60	Daily	T. W.	15 years.	
13	?	10 D.	213	140	—20	200	Daily	T. W.	?	
14	?	10 E	215.	125	+ 7	80	Daily	T. W.	?	
15	379	9 D.	205	130	—11	70	Daily	T. W.	?	
16	?	9 D.	225	...	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small amount of oil.
17	?	9 D.	231	130	+15	30	Daily	T. W.	?	
18	340	8 D.	241	140	+ 8	40	Every 5 days	T. W.	25 years.	
19	341	9 D.	233	134	+10	50	Daily	T. W.	30 years.	
20	?	8 D.	232	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields no large quantity of oil.
21	?	9 D.	201	150	—40	9	Every 13 days	G. W.	?	The well contains much water; it is said to have yielded, five years ago, about 200 viss a day.
22	317	9 E.	230	120	+30	50	Daily	T. W.	30 years.	New well; digging started since six weeks.
23	?	9 E.	. 111	66	+ 1	...	......	T. W.	?	Old well, broken down, yields no oil.
24	?	9 E.	n. m.	...	...	...	......	T. W.	?	

I.—Record of the Wells of the Oil-field of Twingoung—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
25	?	9 E.	235	140	+ 2	80	Daily	T. W.	20 years .	. It is said that this well yielded 200 viss a day about three or four years ago.
26	345	9 E.	243	137	+15	100	Daily	T. W.	?	When the present owner started work, the well yielded 10 viss a day only; by increasing the depth about 5 attaungs the present daily amount was got.
27	?	8 E.	245	140	+12	110	Daily	T. W.	50 years .	. The daily quantity of oil was increased by further digging; before digging was started, the well only yielded 40 viss a day.
28	?	8 E.	230	140	— 3	40	Daily	T. W.	30 years .	. The well contains much water.
29	320	9 E.	60	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
30	321	9 E.	220	120	+20	...	......	T. W.	?	The well yields at present nearly no oil, but much water.
31	335	9 E.	196	...	...	...	......	T. W.	?	Old well, which had broken down and is now worked up again; yields at present no oil.
32	336	9 E.	220	130	+ 4	20	Every 8 days	T. W.	3 years.	
33	347	9 E.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
34	?	9 E.	200	...	...	...	......	G. W.	?	This well yields nearly no oil, and it is hardly worked.
35	?	9 E.	235	160	—31	80	Daily	T. W.	?	} The well contains much water.
36	?	9 E.	227	130	+11	10	Daily	T. W.	?	
37	?	9 E.	n. m.	...	...	...	......	T. W.	?	Old well, which yields at present no oil, but is going to be worked up again.
38	?	9 E.	n. m.	...	...	...	......	?	?	Old well, broken down, yields no oil.
39	351	9 E.	195	150	—54	110	Daily	T. W.	?	The well contains much water; no decrease of oil has been noticed within the last three years.
40	376	10 E.	170	95	+12	40	Every 3 days	T. W.	?	
41	?	10 E.	215	125	+ 7	140	Daily	T. W.	10 years .	. Last year the well yielded 190 viss a day.
42	383	10 E.	187	130	—29	20	Every 6 days	G. W.	30 years .	.
43	382	10 E.	205	120	+ 5	350	Daily	T. W.	10 years .	. The well contains some water.
44	?	10 E.	207	120	+ 7	80	Daily	T. W.	60 years .	. This well yielded, at the depth at 110 attaungs, only nine viss a day. The owner started further digging, which is still going on.

45	388	10 E.	222	130	+ 6	30	Once a month	T. W.	30 years	A short time ago the well yielded 60 viss a day.
46	389	10 E.	223	130	+ 7	150	Daily	T. W.	?	Three years ago the well is said to have yielded 170 viss a day.
47	390	10 E.	129	?	...	...	?	T. W.	?	No further information could be got about this well, which evidently yields only a small amount of oil.
48	?	10 E.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
49	?	10 F.	n. m.	...	...	...	......	P	?	
50	394	10 E.	n. m.	...	...	...	......	G. W.	?	
51	396	10 E.	203	120	+ 3	200	Daily	T. W.	More than 15 years.	Fifteen years ago this well is said to have yielded 800 viss a day.
52	392	10 E.	212	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
53	395	10 E.	197	130	− 19	100	Daily	T. W.	?	
54	352	9 E.	228	140	− 5	200	Daily	T. W.	?	
55	349	9 E.	235	130	+ 19	300	Daily	T. W.	15 years	This well is said to have yielded formerly 700 viss a day.
56	...	9 E.	65	30	...	...	......	T. W.	......	This is a new well where digging has just been started; yields no oil.
57	359	8 F.	171	?	...	...	......	T. W.	......	This well is hardly worked and yields evidently nearly no oil.
58	?	9 F.	241	?	...	?	?	G. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
59	?	9 F.	252	145	+ 11	200	Daily	T. W.	8 years.	
60	326	9 F.	166	80	+ 33	...	......	T. W.	?	This well yields no oil; it is used as a cistern.
61	332	9 F.	262	152	+ 9	40	Daily	T. W.	?	The well contains water at the rate of 10 viss water in 40 viss oil.
62	...	8 F.	249	150	− 1	140	Daily	T. W.	?	No decrease of oil has been noticed within the last four years.
63	323	9 F.	235	115	+ 44	90	Daily	T. W.	30 years	The daily quantity of 40 viss was increased to the present rate by digging 10 attaungs more; the well contains much water.
64	322	9 E.	250	150	+ 0	120	Daily	T. W.	?	The well contains much water.
65	319	9 E.	269	160	+ 3	45	Every 10 days	T. W.	?	At the depth of 140 attaungs the well yielded only 5 viss a day. The daily quantity was increased to its present amount by digging about 20 attaungs more.
66	?	8 E.	...	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
67	?	8 E.	287	157	+ 26	80	Daily	T. W.	20 years.	
68	?	8 E.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
69	300	8 E.	n. m.	...	...	...	......	T. W.	?	
70	301	8 F.	210	?	?	?	?	G. W.	?	This well yields nearly no oil; no further information could be got.
71	?	8 F.	n. m.	?	?	?	?	G. W.	?	Old well, broken down, yields no oil.
72	?	8 F.	n. m.	...	...	...	......	G. W.	?	
73	295	7 F.	245	140	+ 12	30	Daily	T. W.	60 years	The well contains water at the rate of 25 viss water in 30 viss oil.

I.—Record of the Wells of the Oil-field of Twingoung,—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
74	?	8 E.	161	?	...	?	?	T. W.	?	No further information was to be got about this well.
75	299	8 E.	160	90	+ 10	...	......	T. W.	1 year . .	This well has been recently started and has not reached the oil-bearing strata; it yields at present no oil.
76	292	8 E.	224	133	+ 3	...	......	T. W.	3 years . .	This well yields at present no oil.
77	293	7 E.	100	127	...	...	......	T. W.	15 years . .	The well yields at present no oil; it is an old well which had broken down and is not worked up again, the depth of 127 attaungs means the former depth.
78	?	7 E.	258	?	...	?	?	G. W.	?	This well yields evidently only a small amount of oil, as it is very rarely worked; no further data were to be got.
79	?	7 F.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
80	270	7 F.	219	?	...	?	?	T. W.	?	This well yields evidently only a small amount of oil, as it is rarely worked; no further data were to be got.
81	269	7 G.	245	150	— 5	140	Daily	T. W.	?	The well contains much water; two years ago it yielded 180 viss a day.
82	?	7 G.	224	130	+ 8	110	Daily	T. W.	?	The well yielded three years ago 150 viss a day; the well contains no water.
83	?	6 G.	195	130	— 20	...	......	T. W.	?	Old well; broken down and is worked up again; yields no oil at present.
84	226	6 G.	263	150	+ 13	90	Daily	T. W.	?	Two years ago this well is said to have yielded 300 viss a day; the owner tries now to increase the daily quantity of oil by further digging.
85	255	6 G.	193	130	— 23	...	......	T. W.	19 years . .	The well yields at present no oil, as it is broken down and is going to be worked up again; formerly it yielded 40 viss a day.
86	?	6 G.	n. m.	...	...	...	......	T. W.	?	} Old well, broken down, yields no oil.
87	258	6 G.	n. m.	...	...	...	......	G. W.	?	
88	257	6 G.	247	145	6	150	Every 3 days	T. W.	?	

86	260	7 G.	170	?	...	?	?	T. W.	?	This well, which is scarcely worked, yields evidently only a small quantity of oil; no further information was to be got.
90	25?	7 G.	235	?	...	?	?	T. W.	?	
91	?	7 G.	n. m.	?	...	...	......	G. W.	?	Old well, broken down, yields no oil.
92	263	7 H.	n. m.	?	...	...	......	G. W.	?	
93	?	7 H.	n. m.	?	...	...	......	G. W.	?	
94	?	7 H.	n. m.	?	...	...	......	G. W.	?	
95	264	7 H.	136	?	...	...	......	T. W.	?	No further data could be got about this well, which evidently yields nearly no oil.
96	?	6 G.	n. m.	?	...	...	......	T. W.	?	Old well, broken down, yields no oil.
97	?	7 F.	n. m.	?	...	...	......	G. W.	?	
98	?	7 F.	233	143	— 10	35	Every 4 days	T. W.	60 years.	
99	247	7 F.	236	140	+ 3	10	Every 10 days	G. W.	13 years .	The well yielded formerly 30 viss a day.
100	?	7 F.	?	130	...	2	Once a month	G. W.	?	This well yields nearly no oil.
101	244	6 E.	281	?	...	...	......	T. W.	?	No further data were to be got about this well, which evidently yields only a small quantity of oil.
102	?	6 E.	151	90	+ 1	...	......	T. W.	6 months	A recently started well, which yields no oil at present.
103	273	7 E.	183	150	— 77	150	Daily	T. W.	15 years .	Six years ago this well is said to have yielded 260 viss a day.
104	274	7 E.	276	160	+ 10	12	Every 2 days	T. W.	16 years .	This well is said to have yielded formerly when unknown 100 viss a day.
105	?	7 E.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
106	?	7 E.	n. m.	...	...	...	......	T. W.	?	
107	?	7 E.	n. m.	...	...	...	......	T. W.	?	
108	305	8 E.	235	?	...	5	Once a month	T. W.		
109	316	8 E.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
110	315	8 E.	277	165	— 2	20	Daily	T. W.	?	
111	318	8 E.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
112	?	8 E.	n. m.	...	...	...	......	G. W.	?	
113	312	8 D.	250	140	+ 17	20	Every 4 days	T. W.	30 years.	
114	3?7	8 D.	240	140	+ 7	50	Daily	T. W.	30 years.	
115	222	9 C.	187	130	— 30	50	Daily	T. W.	?	Old well, broken down, yields no oil.
116	?	9 C.	n. m.	...	...	...	......	G. W.	?	
117	?	9 C.	n. m.	...	...	...	......	G. W.	?	
118	360	9 C.	205	125	— 3	80	Every 2 months 6 following days.	T. W.	15 years.	
119	?	9 C.	208	120	+ 8	35	Daily	T. W.	70 years.	
120	313	8 D.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
121	314	8 D.	255	170	— 28	3	Once a month	T. W.	10 years .	Six years ago the well yielded 100 viss a day, ten years ago 150 viss.
122	311	8 C.	n. m.	140	...	...	......	T. W.	40 years .	Old well, broken down, and is now going to be worked up again.
123	307	8 C.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
124	?	7 D.	298	170	+ 15	50	Daily	T. W.	70 years.	
125	310	8 C.	283	150	+ 33	200	Daily	T. W.	20 years.	

I.—Record of the Wells of the Oil-field of Twingoung—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
126	309	8 C.	263	160	— 3	100	Daily	T. W.	?	Ten years ago this well is said to have yielded 200 viss a day.
127	?	8 D.	281	167	+ 3	40	Daily	T. W.	?	
128	286	8 D.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
129	285	7 D.	310	170	+ 27	160	Daily	T. W.	?	One year ago the well yielded 180 viss a day.
130	?	7 D.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
131	282	7 D.	280	160	+ 14	500	Daily	T. W.	?	
132	?	7 D.	n. m.	...	...	...	......	G. W.	?	} Old well, broken down, yields no oil.
133	281	7 D.	n. m.	...	...	...	......	T. W.	?	
134	280	7 E.	276	160	+ 10	140	Daily	T. W.	?	
135	279	6 E.	305	160	+ 49	120	Daily	T. W.	19 years.	
136	278	6 D.	282	170	— 1	25	Daily	G. W.	16 years.	
137	239	6 D.	189	?	...	?	?	G. W.	?	Yields nearly no oil.
138	?	6 D.	260	160	— 6	60	Daily	T. W.	6 years .	. Last year the well yielded 80 viss a day.
139	238	6 D.	223	130	+ 7	9	Every 6 days	T. W.	18 years.	
140	No number.	6 D.	102	50	+ 19	...	......	T. W.	3 months .	. This well yields at present no oil, as digging has been started three months ago.
141	235	6 D.	186	?	...	...	......	G. W.	?	
142	240	6 D.	n. m.	...	...	...	......	G. W.	?	
143	277	6 E.	295	?	...	...	......	T. W.	?	No further information could be got about this well, which evidently yields only a small amount of oil.
144	275	6 E.	286	160	+ 20	140	Daily	T. W.	25 years .	. No decrease of oil has been noticed within the last three years.
145	276	6 E.	101	60	1	...	......	T. W.	?	This well yields no oil at present; it is an old well which had tumbled down and is to be repaired.
146	?	6 E.	286	?	...	?	?	G. W.	?	No further information could be got about this well, which is hardly worked and yields only a small quantity or no oil at all.
147	234	6 D.	208	120	+ 8	1	Once every 2 months.	G. W.	?	
148	233	6 D.	273	?	...	?	?	G. W.	?	Yields nearly no oil; no further information could be got.

49	232	6 E.	190	105	+ 15	10	Once a month	T. W.	?	
150	242	6 E.	265	157	+ 4	120	Daily	T. W.	?	
151	?	6 E.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
152	?	6 E.	n. m.	...	...	...	......	T. W.	?	
153	227	5 E.	201	125	— 7	10	Once a month	G. W.	?	
154	?	5 E.	n. m.	?	...	...	......	T. W.	?	New well, but digging has been stopped.
155	?	5 E.	195	130	— 21	28	Every 6 days	G. W.	?	
156	226	5 E.	272	150	+ 22	80	Daily	T. W.	20 years.	
157	?	5 E.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
158	230	5 E.	n. m.	?	...	...	......	T. W.	?	This well, which yields no oil at present, had broken down and is now going to be worked up again from 10 attaungs depth.
159	228	5 E.	197	?	...	?	?	T. W.	?	A newly started well, which yields no oil and where digging is still going on.
160	?	5 E.	n. m.	?	...	...	......	T. W.	?	New well, but further digging has been stopped.
161	191	5 F.	261	130	+ 45	70	Daily	T. W.	30 years.	
162	195	5 E.	195	130	— 21	25	Every 6 days	G. W.	30 years.	
163	?	5 E.	n. m.	...	...	...	......	T. W.	?	
164	?	5 E.	n. m.	...	...	...	......	T. W.	?	
165	?	4 E.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
166	?	5 D.	n. m.	...	...	...	......	G. W.	?	
167	?	4 D.	n. m.	...	...	...	......	T. W.	?	
168	200	4 D.	183	130	— 33	80	Daily	T. W.	?	This well is said to have yielded 100 viss a day about four years ago.
169	?	4 D.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
170	198	4 E.	248	?	...	?	?	T. W.	?	This well is hardly worked and yields either a small quantity or no oil at all.
171	199	4 F.	250	160	— 16	150	Daily	T. W.	?	
172	?	3 E.	n. m.	...	...	...	......	T. W.	?	New well, but further digging has been stopped.
173	?	2 E.	240	138	+ 10	...	......	T. W.	?	This well, where digging is still going on, yields at present no oil.
174	90	2 E.	212	125	+ 4	10	Daily	T. W.	?	
175	?	2 E.	160	100	— 6	8	Daily	T. W.	?	Digging is still going on.
176	?	1 E.	205	?	...	?	?	G. W.	?	No further data could be got about this well, which is hardly worked and yields evidently only a small quantity of oil.
177	No number.	1 E.	n. m.	...	...	...	......	T. W.	?	New well, about 6 feet deep, further digging stopped.
178	No number.	1 E.	120	75	— 5	...	......	T. W.	$1\frac{1}{2}$ months	Recently started well; yields no oil at present.
179	53	1 E.	244	142	+ 8	160	Daily	T. W.	16 years	This well yielded formerly only 30 viss a day; after digging 5 attaungs the amount increased to the present daily quantity.
180	?	1 F.	203	?	...	?	?	T. W.	?	No further information was to be got about this well, but evidently it yields only a small quantity of oil, which is not often drawn up.

I.—Record of the Wells of the Oil-field of Twingoung,—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	Remarks.
1	2	3	4	5	6	7	8	9	10	11
181	20	1 F.	231	?	...	?	?	T. W.	?	No further information could be got about this well, but evidently it only yields a small quantity of oil.
182	?	1 F.	120	?	...	?	?	T. W.	?	No further information was to be got about this well; the yielding of oil is very small. Once drawn, it yielded about 100 viss, and then the stock was exhausted and working was stopped.
183	?	1 F.	191	110	+ 8	80	Daily	T. W.	4 years	This well yielded formerly only 15 viss a day, but by further digging the daily amount was increased.
184	?	2 E.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, not worked.
185	?	2 E.	210	12[illegible]	+ 10	160	Daily	T. W.	40 years	Six years ago this well yielded 100 viss a day, at the depth of 106 attaungs, as it is stated; after digging further 4 attaungs the daily amount increased to its present rate.
186	?	2 E.	...	...	...	...	......	T. W.	?	A new well of about 15 feet depth, where further digging has been stopped.
187	?	2 E.	157	...	...	...	......	T. W.	?	Old well, which does not yield any oil.
188	91	2 E.	185	110	+ 2	230	Daily	T. W.	25 years	At the depth of about 105 attaungs the well yielded 100 viss a day; by digging 4 to 5 attaungs more the daily amount increased to its present rate.
189	?	2 E.	n. m.	...	...	...	......	G. W.	?	} Old well, broken down, yields no oil.
190	56	2 E.	n. m.	...	...	...	......	T. W.	?	
191	57	2 E.	221	130	+ 5	70	Daily	T. W.	15 years	The well yielded formerly 150 viss a day; to increase the present daily amount the owner started fresh digging.
192	58	2 E.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
193	51	2 E.	n. m.	?	...	...	......	T. W.	?	This well evidently yields no oil.
194	23	2 E.	n. m.	...	..	...	......	G. W.	?	Old well, broken down, yields no oil.
195	50	2 E.	200	110	+ 17	50	Daily	T. W.	?	The well contains much water; eight years ago it is stated that it yielded 200 viss a day; further digging is still going on.
196	59	2 E.	185	110	+ 2	5	Once a month	T. W.	20 years.	

197	?	2 E.	n. m.	...	..	...	......	G. W.	?	Old well, broken down, yields no oil.
[illegible]	?	2 E.	n. m.	...	...	...	......	G. W.	?	
[illegible]	[illegible]	2 E.	264	151	+ 12	20	Daily	T. W.	15 years	The well had broken down and was worked up again from the depth of 136 attaungs.
200	?	2 E.	212	?	...	?	?	T. W.	?	A rarely worked well, which evidently yields only a small quantity of oil; no further information was to be got.
201	85	2 E.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
202	?	2 F.	227	?	...	?	?	T. W.	?	No further information was to be got; the well is evidently scarcely worked.
203	60	2 F.	190	120	— 10	?	......	T. W.	?	As this well hardly yields any oil it is used as a kind of reservoir to keep oil from other wells.
204	?	2 F.	180	104	+ 7	40	Every 3 days.	T. W.	25 years.	
205	61	2 F.	231	134	— 9	20	Daily	T. W.	20 years.	
206	?	2 F.	210	?	...	15	Every 4 days two following days.	T. W.	?	The data about this well are uncertain, but evidently the production of oil is not large.
207	?	2 F.	188	?	...	?	?	G. W.	?	No further information could be got, but the well yields evidently only a small quantity of oil.
208	?	1 E.	138	?	...	?	?	T. W.	?	
209	?	1 F.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
210	?	2 F.	210	120	+10	90	Every 3 days	T. W.	10 years.	
211	...	2 F.	190	120	—10	50	Every 2 days	T. W.	25 years.	
212	16	1 F.	239	140	+ 6	20	Daily	T. W.	?	The well contains much water; it yielded formerly 100 viss a day; to increase the present amount further digging is still going on.
213	17	1 F.	160	90	+10	15	Every 10 days, 2 following days.	T. W.	?	
214	14	1 F.	182	108	+ 2	40	Every 3 days.	T. W.	35 years	The well contains much water; formerly it yielded 70 viss a day, but within the last five years no decrease of oil has been noticed.
215	?	1 F.	n. m.	...	...	...	....	T. W.	?	Old well, broken down, yields no oil.
216	?	1 F.	170	110	— 7	40	Every 3 days	T. W.	?	The well contains much water.
217	5	1 F.	244	140	+11	30	Every 2 days	T. W.	?	The well yielded one year ago, at the depth of 130 attaungs, 40 viss a day, but instead of increasing, the daily quantity decreased after further digging.
218	?	1 G.	n. m.	...	...	...	... ..	G. W.	?	
219	?	1 G.	n. m.	...	...	...	......	G. W.	?	
220	?	1 F.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
221	?	1 F.	n. m.	...	...	...	......	T. W.	?	
222	?	1 F.	n. m.	...	...	...	... ..	T. W.	?	
223	47	1 G.	173	?	...	...	.. ...	T. W.	?	No further information was to be got about this well, but evidently it yields only a small quantity of oil.
224	12	1 H.	165	95	+ 7	20	Every 5 days	T. W.	?	One year ago this well yielded 100 viss a day.
225	?	1 H.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
226	?	1 I.	145	?	...	?		T. W.	?	No further information was to be got about this well, but it evidently yields only a small quantity of oil.
227	10	1 I.	n. m.	?	...	?		G. W.	?	

I.—*Record of the Wells of the Oil-field of Twingoung*—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
228	?	1 I.	227	130	+11	20	Daily	T. W.	?	Digging is still going on.
229	?	2 I.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
230	34	2 I.	162	?	...	?	?	T. W.	?	No further information was to be got about these wells, but they evidently yield only a small quantity of oil.
231	35	1 I.	150	?	...	?	?	T. W.	?	
232	39	2 I.	160	?	...	?	?	T. W.	?	
233	?	2 I.	140	?	...	20	Every 5 days	T. W.	?	
234	36	2 I.	n. m.	?	...	?	?	T. W.	?	This well, which is rarely worked, yields evidently only a small quantity of oil.
235	37	2 I.	133	...	...	...	......	T. W.	......	Digging still going on.
236	?	2 I.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
237	71	2 I.	147	75	+22	40	Every 3 days	T. W.	20 years.	
238	40	2 I.	166	100	— 9	35	Once a month	T. W	8 years.	
239	?	2 H.	247	145	+ 5	30	Every 4 days	T.-W.	25 years.	
240	41	2 H.	161	90	+11	8	Once a month	G. W.	6 years	This well yielded formerly (when unknown) 30 viss a day.
241	70	2 H.	149	?	...	?	?	T. W.	?	No further information could be got about this well, but it evidently yields only a small quantity of oil.
242	43	2 H.	146	90	— 4	1	Daily	T. W.	?	Digging is still going on.
243	17	2 H.	145	?	...	?	?	T. W.	?	No further information could be got about this well, which is evidently hardly worked and yields only a small quantity of oil.
244	30	2 H.	242	140	+ 9	300	Daily	T. W.	4 years	At the depth of 137 attaungs this well yielded 2:0 viss; after digging 3 attaungs the present daily amount was got.
245	42	2 H.	246	145	+ 4	30	Daily	T. W.	3 years	Further digging is still going on.
246	76	2 H.	145	?	...	?	?	T. W.	?	No further information could be got about this well, but it evidently yields only a small quantity of oil.
247	75	2 H.	165	80	+32	30	Every 3 days	T. W.	?	This well contains much water.
248	104	2 H.	145	120	—55	20	Once a month	T. W.	?	
249	74	2 I.	100	80	—33	2	Once a month	T. W.	50 years.	

250	?	2 H.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
251	77	2 H.	n. m.	...	...	...	......	T. W.	?	New well, of about 5 feet depth, but further digging stopped.
252	?	2 H.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
253	29	2 H.	233	140	— 0	450	Daily	T. W.	3 years.	Four years ago this well is said to have yielded 1,000 viss a day.
254	?	2 H.	172	?	...	?	?	T. W.	?	No further information could be got about this well, but it evidently yields only a small quantity of oil.
255	?	2 H.	n. m.	...	...	...	......	T. W.	?	New well, further digging stopped.
256	103	2 H.	145	?	...	?	?	T. W.	?	Old well which evidently yields not much oil.
257	108	2 H.	197	?	...	?	?	T. W.	?	No further information could be got about this well, but it evidently yields only a small quantity of oil.
258	?	2 H.	n. m.	?	...	...	......	T. W.	?	New well, but further digging stopped.
259	78	2 H.	151	?	...	?	?	T. W.	?	No further information could be got about this well, but it evidently yields only a small quantity of oil.
260	...	2 H.*	230	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
261	65	2 H.	n. m.	?	...	?	?	T. W.	?	
262	45	2 H.	210	119	+ 11	1	Daily	T. W.	5 years ...	Further digging is still going on.
263	?	2 G.	206	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
264*	63	2 G.	201	120	+ 1	20	Daily	T. W.	8 years ...	No further information could be got about this well, which evidently yields only a small quantity of oil.
265	?	2 G.	228	?	...	?	?	T. W.	?	
266	51	2 G.	130	70	+ 13	...	......	T. W.	?	Old well, broken down, and is being worked up again, yields at present no oil.
267	?	2 G.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
268	?	2 G.	162	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
269	79	2 G.	n. m.	...	...	...	......	T. W.	?	New well, but further digging stopped; no oil.
270	100	2 G.	n. m.	...	...	...	......	T. W.	?	
271	101	2 G.	188	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity or no oil at all.
272	?	2 G.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
273	98	2 G.	n. m.	...	?	...	......	G. W.	?	
274	?	2 G.	n. m,	...	?	...	......	G. W.	?	
275	112	2 G.	159	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity or no oil; digging is still going on.
276	113	2 G.	200	110	+ 17	...	......	T. W.	?	This well, which yields no oil, is used as a kind of reservoir for oil got from other wells.
277	?	2 G.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
278	95	2 F.	195	120	+ 5	70	Daily	T. W.	?	Digging is still going on.
279	?	3 F.	n. m.	...	...	...	......	T. W.	?	A new well, of about 10 feet depth; further digging stopped.

I.—Record of the Wells of the Oil-field of Twingoung—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 21 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
280	94	2 F.	n. m.	?	...	?	?	T. W.	?	No further information could be got about this well, which yields either no oil or only a small quantity.
281	?	2 F.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
282	116	2 E.	235	150	− 15	150	Daily	T. W.	3 years.	
283	?	2 F.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
284	?	2 F.	n. m.	...	...	...	......	T. W.	?	
285	?	3 F.	n. m.	...	...	...	......	T. W.	?	
286	129	3 F.	172	?	...	?	?	T. W.	?	No further information could be got about this well, which yields either no oil or only a small quantity.
287	121	3 G.	229	130	+ 13	140	Daily	T. W.	More than 15 years.	This well yielded at the depth of 125 attaungs only 90 viss a day; after digging 5 attaungs more the present quantity was got.
288	?	3 F.	n. m.	...	...	...	... ..	G. W.	?	Old well, broken down, yields no oil.
289	164	3 F.	221	133	+ 0	12	Twice a month	T. W.	?	Old well, broken down, yields no oil.
290	123	3 G.	n. m.	...	...	...	......	T. W.	?	
291	?	3 G.	n. m.	...	...	...	......	G. W.	?	
292	125	3 G.	193	?	...	20	Every 7 days	G. W.	?	No further information could be got about this well, which yields either no oil or only a small quantity.
293	111	3 G.	180	?	...	?	?	T. W.	?	
294	126	3 G.	172	100	+ 6	10	Every 10 days	G. W.	15 years.	
295	?	3 G.	251	143	+ 13	270	Daily	T. W.	5 years.	Four years ago this well is said to have yielded 1,0[illegible] viss a day.
296	?	3 G.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
297	?	3 H.	n. m.	?	...	...	......	T. W.	?	Yields either a small quantity only or no oil at all.
298	129	3 G.	136	82	+ 0	...	......	T. W.	...	New well where digging has been started only a few months ago; the well yields at present no oil.
299	?	3 H.	n. m.	...	...	...	......	G. W.	?	Old well, broken, yields no oil.
300	109	3 H.	200	135	− 25	50	Every 3 days	G. W.	18 years.	Old well, broken down, yields no oil.
301	?	3 H.	n. m.	...	...	...	......	T. W.	?	
302	133	3 H.	213	?	...	...	......	T. W.	?	No further information could be got about these wells, which evidently yield nearly no oil.
303	?	3 H.	n. m.	?	...	...	......	G. W.	?	
304	?	3 H.	203	?	...	...	......	T. W.	?	

305	105	3 H.	190	120	— 10	100	Daily	T. W.	20 years.	
306	?	3 H.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
307	?	3 H.	230	150	— 20	50	Every 3 days	T. W.		Within the last five years no decrease of oil has been noticed.
308	136	3 I.	240	130	+ 24	100	Daily	T. W.		
309	142	3 H.	232	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
310	?	3 I.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
311	143	3 H.	220	140	— 13	160	Daily	T. W.	6 years.	Formerly this well yielded 600 viss a day.
312	?	3 I.	n. m.	...	...	...	......	T. W.	?	} Old well, broken down, yields no oil.
313	?	3 H.	n. m.	...	...	...	......	G. W.	?	
314	145	3 H.	196	130	— 20	120	Daily	T. W.	?	The well contains much water; the last year it yielded 160 viss a day.
315	147	4 H.	190	120	— 10	20	Every 3 days	T. W.	?	
316	?	4 G.	198	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity or no oil; digging is still going on.
317	159	4 G.	224	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
318	151	4 G.	251	140	+ 18	3	Once a month	T. W.	80 years.	
319	?	4 G.	n. m.	...	...	...	......	T. W.	?	New well of small depth; further digging stopped.
320	155	3 G.	250	150	+ 0	20	Every 10 days 5 following days.	T. W.	?	This well is said to have yielded formerly when unknown 400 viss a day.
321	...	4 G.	253	151	+ 1	6	Daily	T. W.	?	This is an old well, which had broken down and was worked up again since three years; digging is still going on.
322	152	4 G.	245	140	+ 12	100	Daily	T. W.	50 years	This well yielded one year ago only 50 viss; after digging 1 attaung the present daily amount was got.
323	150	4 G.	221	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
324	153	4 G.	215	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil; digging still going on at present.
325	157	4 G.	50	...	...	...	......	T. W.		New well; further digging is stopped.
326	?	4 F.	n. m.	...	...	...	......	T. W.		} Old well, broken down, yields no oil.
327	?	3 F.	n. m.	...	...	...	......	T. W.		
328	160	4 F.	225	130	+ 9	16	Daily	T. W.	?	Old well, which had broken down and is worked up again since three years; further digging is still going on.
329	?	4 F.	n. m.	...	...	...	......	T. W.	?	New well of small depth; further digging is stopped.
330	167	4 F.	242	150	— 8	100	Daily	T. W.	40 years	
331	166	4 F.	250	150	+ 0	8	Once a month	G. W.	...	

I.—*Record of the Wells of the Oil-field of Twingoung*—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
332	168	4 F.	243	150	— 7	220	Daily	T. W.	7 years.	
333	188	4 F.	302	170	+ 19	85	Daily	T. W.	40 years.	
334	187	4 G.	262	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields nearly no oil.
335	?	4 G.	247	?	...	?	?	T. W.	?	
336	170	4 G.	243	150	— 7	30	Every 3 days	T. W.	?	
337	?	4 G.	n. m.	...	...	...	......	G. W.	?	Old well, broken down, yields no oil.
338	171	4 G.	230	150	— 20	200	Daily	T. W.	?	
339	172	4 G.	215	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil; digging still going on.
340	?	4 H.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
341	?	4 H.	n. m.	...	...	...	......	G. W.	?	
342	?	4 H.	n. m.	...	...	...	......	G. W.	?	
343	?	4 G.	n, m.	...	...	...	......	T. W.	?	New well of small depth, about 10 feet; further digging stopped.
344	184	4 H.	250	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
345	175	4 G.	258	?	...	?	?	T. W.	?	
346	183	4 H.	225	140	— 8	50	Daily	T. W.	?	Within the last five years no decrease of oil has been noticed.
347	185	4 G.	245	?	...	?	?	T. W.	?	No further information could be got about this well, which evidently yields only a small quantity of oil.
348	?	5 G.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
349	?	5 H.	233	140	— 0	30	Every 3 days	T. W.	More than 27 years.	
350	170	4 H.	223	140	— 10	90	Daily	T. W.	25 years.	
351	179	5 H.	129	?	...	...	......	T. W.	?	This well yields at present no oil; had broken down and is to be repaired.
352	?	5 H.	n. m.	...	...	...	......	T. W.	?	Old well, broken down, yields no oil.
353	?	4 H.	n. m.	...	...	...	......	G. W.	?	

354	145	4 H.	n. m.	?	...	?	?	T. W.	?	No further information could be got; the well evidently yields only a small quantity of oil.
355	?	4 H.	n. m.	?	...	...	......	G. W.	?	
356	?	3 I.	n. m.	?	...	...	......	G. W.	?	
357	?	3 J.	n. m.	?	...	...	......	G. W.	?	
358	?	5 H.	n. m.	?	...	...	......	G. W.	?	
359	?	10 E.	n. m.	?	...	...	......	T. W.	?	
360	?	7 E.	n. m.	?	...	...	......	T. W.	?	
361	69	2 H.	n. m.	?	...	...	......	T. W.	?	
362	?	6 B.	n. m.	?	...	...	......	G. W.	?	
363	?	6 B.	n. m.	?	...	...	......	G. W.	?	
364	?	5 B.	n. m.	?	...	...	......	G. W.	?	
365	?	5 A.	n. m.	?	...	...	......	G. W.	?	Old well, broken down, yields no oil.
366	?	5 A.	n. m.	?	...	...	......	G. W.	?	
367	?	4 A.	n. m.	?	...	...	......	G. W.	?	
368	?	4 A.	n. m.	?	...	...	......	G. W.	?	
369	?	5 B.	n. m.	?	...	...	......	T. W.	?	
370	?	5 B.	n. m.	?	...	...	......	G. W.	?	
371	?	5 B.	n. m.	?	...	...	......	G. W.	?	
372	?	5 B.	n. m.	?	...	...	......	G. W.	?	
373	?	5 B.	n. m.	?	...	...	......	G. W.	?	
374	?	5 B.	n. m.	?	...	...	......	G. W.	?	
375	?	6 C.	n. m.	?	...	...	......	T. W.	?	

BEME.

Key to find from a given old Burmese number the consecutive number given by me to the wells of Beme.

Remarks.—*Burmese numbers in Roman : 390.*
Consecutive numbers in Italics : 7.

Burmese No.	Consecutive No.	Burmese No.	Consecutive No.	Burmese No.	Consecutive No.
390	*7*	440	...	490	*49*
391	...	441	*76*	491	*50*
392	...	442	...	492	*51*
393	...	443	*39*	493	*53*
394	...	444	*40*	494	*54*
395	...	445	...	495	*55*
396	...	446	*88*	496	*52*
397	*68*	447	*86*	497	*56*
398	...	448	*87*	498	*57*
399	*4*	449	*100*	499	...
400	*3*	450	*102*	500	*58*
401	...	451	*103*	501	*59*
402	*2*	452	*106*	502	*67*
403	*6*	453	...	503	*66*
404	...	454	...	504	*65*
405	*17*	455	*107*	505	*63*
406	*16*	456	*113*	506	*64*
407	*18*	457	*112*	507	*60*
408	*19*	458	*111*	508	*61*
409	*21*	459	...	509	*62*
410	*20*	460	...	510	*126*
411	...	461	*114*	511	*127*
412	*27*	462	...	512	*125*
413		463	...	513	*128*
414	*28*	464	...	514	*122*
415	*23*	465	...	515	*123*
416	...	466	*132*	516	*129*
417	...	467	...	517	*124*
418	*24*	468	...	518	*121*
419	...	469	...	519	*120*
420	*26*	470	...	520	*130*
421	*0*	471	*89*	521	*117*
422	*13*	472	*75*	522	*116*
423	*10*	473	...	523	*118*
424	*11*	474	*93*	524	*115*
425	*12*	475	*94*	525	*119*
426	*14*	476	*92*	526	*131*
427	...	477	*95*	527	*140*
428	*30*	478	*96*	528	...
429	*90*	479	*44*	529	...
430	*31*	480	...	530	*141*
431	*32*	481	...	531	...
432	*33*	482	...	532	...
433	*34*	483	*77*	533	...
434	*35*	484	*78*	534	*144*
435	*41*	485	*79*	535	*145*
436	*36*	486	*80*	536	*146*
437	*37*	487	*46*	537	*147*
438	*38*	488	*47*	538	*148*
439	...	489	*48*	539	*149*

II.—Record of the Wells of the Oil-field of Beme.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
1	?	19 C.	n. m.	n. m.	...	...	......	G. W.	Unknown .	Old well, broken down.
2	402	19 C.	n. m.	n. m.	...	...	......	G. W.	Unknown .	
3	400	19 D.	110	156	+ 150	70	Daily	T. W.	30 years . .	Seven years ago, this well is said to have yielded about 170 viss a day. The native statements regarding the depth are obviously utterly wrong.
4	399	19 D.	n. m.	n. m.	...	...	......	T. W.	Unknown .	Old well, broken down, not worked.
5	?	19 D.	n. m.	n. m.	...	...	......	T. W.	Unknown .	
6	403	19 C.	128	150	+ 122	70	Daily	G. W.	30 years . .	Two years ago this well is said to have yielded 150 viss a day. The native statements regarding the depth are obviously wrong.
7	390	19 C.	150	135	+ 74	105	Daily	T. W.	Unknown .	The oil is mixed with much water. The native statements regarding the depth are obviously wrong.
8	?	19 C.	n. m.	n. m.	...	...	......	G. W.	Unknown .	Old well, broken down, not worked.
9	421	20 D.	155	150	+ 95	75	Daily	T. W.	35 years . .	Twenty years ago this well is said to have yielded 100 viss a day (?) The native statements regarding the depth are obviously wrong.
10	423	21 D.	60	40	+ 6	...	Once a month	T. W.	Unknown .	This well yields nearly no oil; oil is drawn up once a month. The amount then got is about 30 viss, as the oil is mixed with much water.
11	424	21 E.	n. m.	n. m.	...	...	......	T. W.	Unknown .	Old well, broken down, not worked.
12	425	21 E.	n. m.	100	...	...	......	T. W.	Unknown .	
13	422	21 D.	60	40	+ 6	1	Once a month	G. W.	Unknown .	This well yields nearly no oil; oil is drawn up once a month; the amount then got is about 10 viss.
14	426	21 D.	110	100	+ 83	10	Daily	T. W.	Unknown .	The well contains much water. The native statements regarding the depth are obviously wrong.
15	?	21 E.	n. m.	n. m.	...	...	......	T. W.	Unknown .	Old well, tumbled down, not worked.
16	406	19 C.	n. m.	n. m.	...	...	......	G. W.	Unknown .	Old well, broken down, unproductive.
17	405	19 C.	105	80	+ 28	...	Once a month	G. W.	40 years . .	This well yields at present nearly no oil. The amount got once a month is about 10 viss, as the well contains much water. Formerly, 9 years ago, this well is said to have yielded 100 viss a day.

II.—Record of the Wells of the Oil-field of Beme—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
18	407	19 C.	215	130	+ 1	60	Daily	G. W.	40 years	Twenty years ago this well is said to have yielded 200 viss a day.
19	408	19 C.	n. m.	n. m.	...	...	......	T. W.	?	This is a well, about 5 feet deep, where further digging has been stopped.
20	410	19 C.	245	150	+ 5	100	Daily	T. W.	60 years.	
21	409	19 C.	245	144	— 4	110	Daily	T. W.	100 years	This well is said to have yielded formerly (when unknown) 300 viss a day.
22	?	20 D.	n. m.	n. m.	...	...	......	G. W.	Unknown	Old well, broken down, not worked.
23	415	20 D.	205	156	+ 55	90	Daily	T. W.	60 years	This well is said to have yielded formerly (when unknown) 400 viss a day, *vide*—No. 3.
24	418	20 D.	210	150	+ 40	70	Daily	T. W.	60 years	This well is said to have yielded formerly, 30 years ago, 300 viss a day, *vide*—No. 3.
25	?	20 D.	120	80	+ 13	1	Once a month	T. W.	Unknown	The well, which contains much water, yields nearly no oil, as the amount got at present is not more than 30 viss a month; nine years ago it is said to have yielded 80 viss a day.
26	420	20 D.	132	80	+ 1	40	Daily	T. W.	Unknown	The well contains much water.
27	412	20 D.	225	130	— 9	60	Daily	T. W.	50 years	The well contains little water.
28	414	20 D.	235	150	+ 15	80	Daily	G. W.	60 years	This well is said to have yielded formerly, about 40 years ago, 300 viss a day.
29	425 ?	21 E.	n. m.	n. m.	...	...	....	T. W.	Unknown	Old well, broken down, no oil.
30	428	21 D.	95	60	+ 5	40	Daily	T. W.	100 years	The well contains much water.
31	430	21 D.	120	80	+ 13	90	Daily	T. W.	Unknown	The well contains much water; it is said to have yielded formerly, nine years ago, 110 viss a day.
32	431	21 D.	n. m.	n. m.	...	...	......	T. W.	Unknown	Old well, broken down, yields no oil.
33	432	21 D.	70	50	+ 13	10	Three times a month.	T. W.	100 years	The well contains much water.
34	433	21 D.	n. m.	n. m.	...	...	......	T. W.	Unknown	Old well, broken down, yields no oil.
35	?	21 D.	n. m.	n. m.	...	...	......	G. W.	Unknown	
36	?	21 C.	n. m.	n. m.	...	...	......	T. W.	Unknown	
37	437	21 C.	230	153	+ 25	165	Daily	T. W.	100 years	

38	438	21 C.	145	90	+ 5	...	......	T. W.	......	This is a new well where digging has been started a short time ago.
39	434	21 C.	262	150	— 12	110	Daily	T. W.	100 years.	
40	444	21 C.	250	150	— 0	50	Daily	T. W.	80 years.	
41	435	21 C.	270	150	— 20	3	Once a month	T. W.	80 years .	The well yields at present nearly no oil; the owner tries to get more by further digging. The well is said to have yielded formerly, when unknown, 100 viss a day.
42	?	21 D.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
43	?	21 D.	n. m.	n. m.	...	...	......	T. W.	?	
44	479	21 C.	208	120	— 8	40	Daily	T. W.	80 years.	
45	?	21 C.	190	150	+ 60	60	Daily	T. W.	100 years .	The well contains much water; ten years ago it is said to have yielded 200 viss a day,—*vide* No. 3.
46	487	21 C.	227	157	+ 35	90	Daily	T. W.	100 years .	The native statements regarding the depth are evidently exaggerated.
47	488	21 B.	230	140	+ 3	60	Daily	T. W.	100 years.	
48	489	21 B.	207	130	+ 9	70	Daily	T. W.	100 years.	
49	490	21 B.	236	145	+ 5	90	Daily	T. W.	100 years.	
50	491	21 B.	117	65	— 9	...	......	T. W.	?	Old well, which was broken down and is now to be repaired again; no oil at present.
51	492	21 B.	235	150	+ 15	105	Daily	T. W.	100 years .	The owner tries to get more oil by further digging and increasing the depth of the well.
52	496	21 B.	203	120	— 3	80	Daily	T. W.	100 years .	
53	493	21 B.	210	130	+ 6	40	Daily	T. W.	100 years .	The native statements regarding the depth are evidently highly exaggerated.
54	494	21 B.	195	157	+ 66	10	Once a month	T. W.	100 years .	
55	495	21 B.	n. m.	80	...	...	......	T. W.	......	This well has just begun to be dug; yields no oil.
56	497	21 B.	205	110	— 22	20	Daily	T. W.	100 years.	
57	498	21 B.	205	100	— 49	10	Once a month	T. W.	30 years.	
58	500	21 B.	172	100	+ 6	10	Once a month	T. W.	30 years.	
59	501	21 A.	250	130	— 34	30	Daily	T. W.	80 years.	
60	507	21 A.	n. m.	n. m.	...	...	......	T. W.	30 years.	Old well, broken down, yields no oil.
61	508	21 A.	n. m.	n. m.	...	...	......	T. W.	?	New well, about 5 feet deep; further digging stopped.
62	509	21 A.	240	130	— 24	80	Daily	T. W.	100 years .	The owner tries to increase the amount of oil by further digging.
63	505	21 A.	105	120	+ 95	40	Daily	T. W.	100 years .	The native statements regarding the depth are evidently highly exaggerated.
64	506	21 A.	n. m.	n. m.	...	...	......	T. W.	?	New well, about 5 to 6 feep deep; further digging has been stopped.
65	504	21 A.	252	145	— 11	105	Daily	T. W.	100 years.	
66	?	21 A.	207	110	— 24	70	Daily	T. W.	100 years.	
67	502	21 B.	230	130	— 14	70	Daily	T. W.	100 years.	
68	397	20 E.	n. m.	n. m.	...	...	......	G. W.	?	Old wells, broken down, yield no oil.
69	?	19 C.	n. m.	n. m.	...	...	......	G. W.	?	
70	?	20 D.	n. m.	n. m.	...	...	......	G. W.	?	
71	?	20 D.	n. m.	n. m.	...	...	......	G. W.	?	

II.—Record of the Wells of the Oil-field of Beme—continued.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
72	?	20 C.	n. m.	n. m.	...	...	......	G. W.	?	Old wells, broken down, yield no oil.
73	?	20 C.	n. m.	n. m.	...	...	......	G. W.	?	
74	495	20 C.	190	156	+ 70	160	Daily	T. W.	100 years.	The native statements regarding the depth are obviously wrong.
75	472	20 C.	100	100	+ 66	10	Once a month	G. W.	?	*Vide* No. 74.
76	441	20 B.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
77	483	21 B.	n. m.	n. m.	...	...	......	T. W.	?	
78	484	20 B.	85	70	+ 31	10	Once a month	T. W.	100 years.	
79	485	20 B.	60	80	+ 73	1	Once a month	T. W.	100 years.	This well yields nearly no oil,—*vide* No. 74.
80	486	21 B.	n. m.	n. m.	...	...	......	T. W.	?	Old wells, broken down, yield no oil.
81	?	20 A.	n. m.	n. m.	...	...	......	T. W.	?	
82	?	20 A.	n. m.	n. m.	...	...	......	T. W.	?	
83	?	20 A.	n. m.	n. m.	...	...	......	T. W.	?	
84	?	20 D.	n. m.	n. m.	...	...	......	T. W.	?	
85	?	21 D.	n. m.	n. m.	...	...	......	T. W.	?	
86	447	21 D.	243	130	— 27	30	Daily	T. W.	100 years.	The well contains much water.
87	448	21 D.	155	120	+ 45	30	Daily	T. W.	100 years.	
88	446	21 D.	195	110	— 12	10	Once a month	G. W.	30 years.	
89	471	21 D.	270	150	— 20	115	Daily	T. W.	100 years.	
90	?	22 D.	n. m.	n. m.	...	...	......	T. W.	......	New well, is about 3 feet deep; further digging stopped; yields no oil.
91	472	21 D.	185	120	+ 2	10	Once a month	G. W.	30 years.	Old well, broken down, yields no oil.
92	476	22 C.	n. m.	n. m.	...	...	......	G. W.	?	
93	474	22 C.	195	110	— 12	10	Once a month	G. W.	30 years.	
94	475	22 D.	n. m.	100	...	10	......	G. W.	30 years.	
95	477	22 C.	n. m.	n. m.	...	...	......	G. W.	?	Old well, broken down, yields no oil.
96	478	22 C.	n. m.	n. m.	...	...	......	G. W.	?	
97	No number.	22 C.	...	...	...	...	......	T. W.	?	This well is going to be dug, but digging has not started at present.
98	?	22 C.	n. m.	n. m.	...	...	......	G. W.	?	Old well, broken down, yields no oil.
99	429	21 D.	n. m.	n. m.	...	...	......	T. W.	?	

100	449	21 D.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
101	?	21 A.	n. m.	n. m.	...	...	......	T. W.	?	
102	450	22 D.	n. m.	70	...	...	......	T. W.	?	Old well, broken down, is going to be worked up again at present.
103	451	22 D.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
104	?	22 D.	n. m.	n. m.	...	...	......	T. W.	?	Old well, yields no oil.
105	?	22 D.	n. m.	n. m.	...	...	......	T. W.	?	Old well; digging stopped.
106	452	22 D.	105	110	+ 78	50	Daily	T. W.	100 years.	The well contains much water; it is said to have yielded formerly, 20 years ago, 80 viss a day. The native statements regarding the depth are obviously wrong.
107	455	22 D.	223	135	+ 1	40	Daily	T. W.	70 years.	
108	?	22 D.	n. m.	n. m.	...	...	......	T. W.	?	This well, which is broken down and not worked since 20 years, is said to have yielded, at 147 attaungs depth, 80 years ago, 2,000 viss a day.
109	?	22 D.	n. m.	n. m.	...	...	......	T. W.	?	Old wells, broken down, yielding no oil.
110	?	23 D.	n. m.	n. m.	...	...	......	T. W.	?	
111	458	22 D.	n. m.	n. m.	...	...	......	T. W.	?	
112	457	22 D.	n. m.	n. m.	...	...	......	T. W.	?	
113	456	22 C.	190	110	—113	40	Daily	T. W.	100 years.	This well is said to have yielded, 20 years ago, 170 viss a day.
114	461	23 C.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
115	524	22 C.	232	140	+ 1	70	Daily	T. W.	?	The well contains much water.
116	522	22 C.	248	150	+ 2	10	Once a month	T. W.	100 years.	
117	521	22 B.	250	152	+ 3	40	Daily	T. W.	100 years.	
118	523	23 B.	255	153	+ 0	40	Daily	T. W.	100 years.	
119	525	23 C.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
120	519	22 B.	245	153	+ 10	50	Daily	T. W.	100 years.	
121	518	22 B.	250	140	— 17	30	Daily	T. W.	100 years.	
122	514	22 B.	260	155	— 2	60	Daily	T. W.	100 years.	
123	515	22 B.	n. m.	n. m.	...	...	......	T. W.	?	Old well, broken down, yields no oil.
124	517	22 B.	227	140	+ 6	15	Once a month	T. W.	100 years.	
125	512	22 A.	250	140	— 17	70	Daily	T. W.	30 years.	
126	510	22 A.	190	123	+ 15	15	Once a month	T. W.	70 years.	
127	?	23 B.	n. m.	n. m.	...	...	......	T. W.	70 years	Old well, broken down, yields no oil.
128	513	23 B.	240	140	— 2	40	Daily	T. W.	100 years.	
129	516	23 B.	251	155	+ 2	60	Daily	T. W.	100 years.	
130	520	23 B.	250	157	+ 11	70	Daily	T. W.	100 years.	
131	526	23 C.	215	140	+ 19	15	Once a month	T. W.	100 years.	
132	466	23 C.	232	140	+ 1	15	Once a month	T. W.	70 years.	
133	?	23 D.	120	100	+ 46	...	......	T. W.	100 years.	Old well, which yields no oil.
134	?	23 D.	135	100	+ 31	15	Once a month	T. W.	100 years.	
135	?	23 D.	n. m.	n. m.	...	...	......	G. W.	?	Old well, broken down, yields no oil.
136	?	23 D.	102	100	+ 64	15	Once a month	T. W.	100 years.	This well contains much water.
137	?	23 D.	n. m.	n. m.	...	...	......	T. W.	?	Old wells, broken down, yielding no oil.
138	?	23 D.	n. m.	n. m.	...	...	......	G. W.	?	

II.—Record of the Wells of the Oil-field of Beme—concluded.

Consecutive No.	Old No.	Locality.	Depth in feet.	Stated depth in attaungs, at 20 inches.	Difference between 4 and 5 in feet.	Stated daily yield in viss.	How often oil is drawn up.	Proprietor of the well.	Stated age of the well.	REMARKS.
1	2	3	4	5	6	7	8	9	10	11
139	?	22 D.	n. m.	n. m.	...	...	......	T. W.	?	Old wells, broken down, yielding no oil.
140	527	24 A.	n. m.	n. m.	...	...	......	T. W.	70 years . .	
141	530	24 B.	105	100	+ 61	...	......	T. W.	70 years . .	This well yields at present no oil, but it is said to have yielded 20 years ago 100 viss. The owner tries to get oil by increasing the depth of the well.
142	531	24 B.	n. m.	n. m.	...	...	......	G. W.	?	Old wells, broken down, yielding no oil.
143	532	24 B.	n. m.	n. m.	...	...	......	T. W.	?	
144	534	23 B.	n. m.	n. m.	...	...	......	T. W.	?	
145	535	24 B.	n. m.	n. m.	...	...	......	T. W.	?	
146	536	24 B.	n. m.	n. m.	...	...	......	T. W.	?	
147	537	24 B.	n. m.	n. m.	...	...	......	T. W.	?	
148	538	24 B.	n. m.	n. m.	...	...	......	T. W.	?	
149	539	23 B.	n. m.	n. m.	...	...	......	G. W.	?	
150	?	24 C.	n. m.	n. m.	...	...	......	T. W.	?	
151	?	22 C.	n. m.	n. m.	...	...	......	T. W.	?	

The gypsum *of the* Nehal Naddi, Kumaun: *by* C. S. MIDDLEMISS, B.A.' *Assistant Superintendent, Geological Survey of India.* (With a plate.)

The gypsum of this locality is briefly referred to in the "Manual of the Geology of India" in the following words:[1] "The most promising source is near the Nihal Bridge on the [old] road between Kaladhungi and Naini Tal; plaster of Paris of good quality has been made from it." Before my survey operations had taken me there my attention was directed to the gypsum by Col. Thomason, R.E., and I shortly afterwards visited the place in the company of Mr. W. F. Wells, C.S., Offg. Director of Land Records and Agriculture, N.-W.-P. and Oudh, who was anxious to find a source of gypsum, as there was a demand for it for fertilizing purposes. Still later I showed the beds to Lieutenant-Colonel Campbell, B.S.C., of the Forest Department. A rough cart-track has since been made between the quarries and the Kaladhungi-Haldwani road, and about 4,000 maunds collected for despatch to Tirhoot. So far very little quarrying has been done, scarcely anything but loose blocks having been picked up and gathered together in heaps. Although, therefore, no steps have been taken to ascertain the actual depth to which the beds of gypsum go, or their full thickness, the following notes and rough estimate of the probable amount available may be less of use.

Position and mode of occurrence.

Although very small quantities of gypsum are found in more than one locality in the neighbourhood of Naini Tal, the deposit we are considering at the present moment is situated south of the main boundary fault which divides the Sub-Himalayan from the Himalayan groups of formations. There are two positions on the right bank of the Nehal N., between Nehalpur and a point a mile north of Dhapla village, where the mineral is aggregated into considerable beds. Further details as to localities for quarrying will be given later. Unlike the gypsum of the Salt Range, and like that of Spiti, described by Mr. F. R. Mallet,[2] the deposit is not a stratified but a superficial one. It clothes the hill-side in amorphous masses associated with the re-made rock from underneath and with scree material which has descended from the array of bare precipices, forming what are known as the "landslips" south of Ayarpatha peak. The bed-rock on which it rests belongs to the Nahan stage of the sub-Himalayan group, being composed of sandstone, with partings of shale or hardened clay. The beds are nearly horizontal, having a slight dip of from 3° to 10° N.N.E. At the points where the gypsum has been formed, the side of the valley cut out in the sandstone is fairly steep, the slope being about 40°. Conforming to this slope comes a more or less irregularly bedded surface accumulation of material in which the gypsum is aggregated. This surface material is partly older than, and partly contemporaneous with, the gravel banks and terraces which line the river banks. Its composition is as follows:—In some places it is as much as 80 or 90 feet in thickness and is made up largely (especially in the parts higher up the hillside) of fragments of purple and grey shale of angular form, derived from the Nahan rocks, set in earthy material. But there are also intermixed many pieces of limestone and

[1] Manual of the Geology of India, Part III, Economic Geology, p. 454.

[2] Mem. Geol. Surv. of India, Vol. V, Part II, p. 153.

slate from the Himalayan series at the head of the Nehal N. This surface accumulation possesses two distinct colours, *viz.* purple and a greenish grey or black. The lower 45 feet, resting on the Nahan sandstone, are of the dark neutral tints. In this there are no beds of gypsum, but an efflorescence gives it superficially a white appearance which at first suggests a large amount within. A similar efflorescence is visible here and there among the recent gravels of the river-terraces, both in this river and in the Ballia ravine. The upper 45 feet take on a distinctly purple colour from the larger intermixture of purple shales in a fragmentary and much disintegrated state. It is in these purplish beds that the gypsum occurs.

As shown in the accompanying diagram, the gypsum is present in lenticular bands or layers, which are not continuous, but which thin out in one place and begin again in another. At the highest point on the hill-side at which the purple surface material is found, the included layers of gypsum are very thin and closely aggregated: they are like a set of veins which pursue roughly parallel courses in a wavy irregular manner; and they give blocks of about a foot square or less. These lenticular layers of the mineral slope down the hillside at an angle of about 40°, following in a rough and uncertain way the general slope of the débris in which they are imbedded. As they are traced downwards the thin bands give place to thicker and more massive beds: the isolated 'fingers' unite as it were, so that near the base of the slope of débris the gypsum is seen at its best.

There is no selenite, or coarsely crystalline form of gypsum, as far as I have seen.

Form of gypsum.

That present is uniformly of a white, or whitey grey colour, though very occasionally it is flesh-red. A broken surface sparkles like a mass of snow, owing to the innumerable micro-crystals of which it is composed. Where the lenticular layers thicken they become denser, purer, and massive. Even then, however, they are interrupted, here and there, by shaly impurities of shining greenish colour. On the other hand, near the upper and lower surfaces of the bed and in those upper parts of the hill-side where the beds are at their thinnest, the gypsum is not so pure, but is largely mixed with shale and sometimes brecciated with it into a rock that is half gypsum and half shale. There are, therefore, roughly speaking, a better and a worse variety of the gypsum, looked at it from a commercial point of view.

As deducible from its irregular collection on the surface of the hill-sides the

Origin of the gypsum.

gypsum does not seem to have been formed over any large area, nor can it have been chemically precipitated from a surcharged lake or from any body of water which has been ponded back. The history of the Sub-Himalaya, through Recent and Tertiary times, is unanimous in testifying that the margin of the Himalaya has always been under the same conditions of rapid sub-aerial decay by streams and torrents, as are witnessed to-day; no sea nor expanse of water having washed its foot since nummulitic times. The explanation of the gypseous deposits is the same here as Mr. Mallet propounded for the Spiti gypsum. They are manifestly the result of springs of water which, even at the present day, are seen to be laying down the mineral on a small scale. Whether the ultimate source of the sulphur which enters into the composition of the gypsum be due to percolation of water through pyritous slates or whether a defunct volcanic origin is indicated, it is certain that the immediate explanation of the gypsum is in the

springs charged with sulphuretted hydrogen which issue at at least two points near Naini Tal and in the large amount of massive limestone in the vicinity.

Amount of gypsum available.

An estimate of the amount of the mineral, based on what can be seen at the surface, is liable to a certain error from the fact that the beds are not regular strata of the nature of coal seams, but are prone to thicken and thin out, to be developed in one place and to be suddenly absent in another. The first of the gypsum localities is about 1½ miles N. of Dhapla village. For a distance of about 70 yards from the south end of the exposure the mineral is partially laid bare up the slope of the hill by weathering and by such working as has already taken place. A side-stream to the north of this gives a section somewhat imperfect, but which, taken with other observations on the face of the quarry, indicates] a set of lenticular beds swelling out below and which may be represented in the aggregate as a wedge-shaped mass of gypsum; the thicker end being the bottom of the slope and the thinner end being the top of it. Taking the thickness of the wedge at the base as 10 feet and the thickness at the top at 2 feet, we have, with a length of 70 yards and a breadth of 40 yards, about 151,000 maunds represented. As already stated, the still more recent gravels forming the terrace at the foot of the slope cover up the continuation of the gypsum beds downwards; but, as it is impossible to say whether the wedge goes on thickening downwards or becomes thinner again, I have taken an intermediate value of 6 feet as the probable thickness for a further distance of 20 yards below the gravel terrace. Another 75,500 maunds may therefore be added, giving a total of 226,500 maunds. North of the little side-stream just mentioned the gypsum is not laid bare on the slope of the hillside, but is covered up by more surface screen material for a distance of 200 yards up the river as far as the next side-stream which descends from the 4,658 feet hill. The surface material is continuous all the way with its two characteristic colours, and the outcrop of various bands of gypsum among purple débris indicate in a sense their persistence for these 200 yards. Thus, with an average breadth of 40 yards and thickness of 6 feet, we get 432,000 maunds represented. The next exposure is a little over ¼ mile beyond the last locality, between which two places bed-rock, consisting of Nahan sandstone, is free from the gypsum-bearing surface débris. This exposure is about 200 yards long, but it does not reach so far up the hillside and is not quite so thick as in the last place. In breadth it is about 20 yards, which, with an average thickness of 5 feet, gives about 180,000 maunds. There are some very small veins of gypsum still higher up the Nehal N., but none worth quarrying. The total amount of gypsum available, therefore, calculated on measurements which may be slightly below the mark but are not above it, is 838,500 maunds, or 37,430 tons.

On some of the Materials *for* Pottery *obtainable in the neighbourhood of* Jabalpur, *and of* Umaria; *by* F. R. MALLET, *Superintendent, Geological Survey of India.*

For many years past ornamental bricks, and other articles, have been made, at Jabalpur, from certain white clays which occur in the immediate neighbourhood of the station. Struck with their apparently excellent quality, and impressed with the idea that they could be used for the production of a superior class of pottery, Mr. J. H. Glass, C.E., then Executive Engineer of the division, sent specimens of these clays, in 1881, to Mr. Dejoux for analysis. The results obtained confirming the opinion already formed, Mr. Glass submitted a scheme to the Government of the Central Provinces for the establishment of pottery works, on an experimental scale, in the Central Prison. This project has remained in abeyance, although not forgotten, and comparatively recently the Geological Survey has been applied to for any information available respecting the clays in question, and subsidiary materials such as felspar and flint. In consequence of this requisition, I was directed, in January last, to examine the neighbourhood of Jabalpur with reference to the points alluded to above.

At the time Mr. Glass's Memorandum was penned the existence of the white clays elsewhere than near Jabalpur does not appear to have been known, and, as a source of fuel, he looked to the coal at Lameta Ghát, about 9 miles distant, which might be supplemented by that of Mopáni. But, since then, the Umaria coal-field has been opened out, and clay, identical with that of Jabalpur, has been found within a reasonable distance from the colliery. These facts were sufficient to suggest that Umaria, with its cheap and abundant coal, might be a more advantageous site for pottery works than Jabalpur, and I accordingly made some examination of that neighbourhood also.[1] Had circumstances allowed I would have been glad to spend a longer time there, as well as in the Jabalpur district, but, although I was not able to do all I wished, I still saw enough to form a decided opinion on the most important points.

CLAYS.

Jabalpur.

The white clays of Jabalpur are already well known through the efforts of Mr. Glass to bring their excellent qualities into notice. They are interstratified with the soft white sandstones of the Upper Gondwánas (Jabalpur group), into which they frequently pass vertically by insensible gradations, so that in many sections it is difficult to say where the line should be drawn between sandy clay and argillaceous sandstone. In other sections, again, the line of demarcation between the two rocks is comparatively sharply marked, and two or more beds of clay may be noticed with some feet or yards of sandstone between. In some of the pits which have been opened, 4 or 5 feet of good clay is exposed without any intermixture with that of a lower quality. The varying

[1] With the exception of that south and south-west of Jabalpur, the entire area referred to in the following notes is included in the map attached to my paper on the Iron Ores, &c., of the north-eastern part of the district (Records, G. S. I., Vol. XVI, part 2).

character of the clay is well indicated by the analyses quoted by Mr. Glass, one sample yielding (after treatment with acid and elutriation) 87·2 per cent. of clay, with 5·1 of sand, while in another the proportions were 39·6 and 52·2.

The clays attain their greatest development, both vertically and superficially, in the vicinity of Chota Simla. At one place, on the southern flank of the hill, nearly fifty feet of clay and earthy sandstone is exposed, the lower beds extending for some hundred yards into the plain to the south-east and west of the outlying hill west of Chota Simla. The clays are also exposed in the railway cutting, and all round the hill north of the line; they may likewise be traced eastwards, along both sides of the Marjadlia Valley, as far as the edge of the trappean area. Here, however, they are much thinner, a fact which is connected with the unconformity of the overlying Lameta limestone. The preservation of the clays, near Jabalpur, is largely due to the protection from denudation they have received from the more resistant limestone above.

The clay is whitish, or sometimes pale gray. The latter variety, however, turns white on ignition, the colour being doubtless due to a trace of carbonaceous matter. A slight reddish tinge is also sometimes noticeable, due to iron. The purer clay is highly plastic and very infusible. Small bricks measuring $1\frac{3}{4}'' \times \frac{1}{2}'' \times \frac{1}{4}$," after exposure for an hour to a dazzling white heat in an injector gas furnace, were found to have contracted $\frac{1}{14}$th in length, to have retained their sharp edges, and to have become sufficiently hard to scratch glass, the structure being finely vesicular. Those made of grayish clay were pure white, or very nearly so, while those of clay with a slight reddish tinge were also white, although less pure in tint.

A sample of clay, taken from a pit at the base of the hill west of the railway, has been analysed by Mr. Blyth with the following result:—

	Air-dried clay.	Clay dried at 100C.
Moisture (loss at 100C.)	1·73	...
Loss on ignition	7·80	7·92
Alumina	24·05	24·41
Ferric oxide	2·88	2·92
Lime	·75	·76
Magnesia	·59	·60
Silica (combined)	27·14	27·54
Siliceous sand	35·33	35·85
TOTAL	100·27	100·00

The ferric oxide exists in the free state, being dissolved out completely, or nearly so, by cold strong hydrochloric acid, which does not attack the silicate of alumina. The same reagent also extracts the lime and magnesia, which, however, would appear to be combined with silica, as there is no carbonic acid present. Deducting the above, and the sand, we have, as the composition of the true clay—

Loss on ignition	13·23
Alumina	40·77
Silica[1]	46·00

[1] Some deduction should be made from the silica on account of that combined with the lime and magnesia.

which is very close to the theoretical composition ($H_2O \cdot Al_2O_3 \cdot 2SiO_2 + H_2O$ or $H_2 \; Al_2 \; Si_2 \; O_8 + H_2O$) as given below :—

Water	13·92
Alumina	39·68
Silica	46·40
TOTAL	100·00

Lameta.

Clays of a character similar to those of Jabalpur, except that as a whole they are more ferruginous, overlie the coal of Lameta Ghát.[1] Some parts are as white as the clays of Chota Simla, but others are yellowish or reddish, and even contain nodules of ochreous ferric oxide. Some distance to the eastward of the quarry described on page 146, associated with the clays just mentioned, there is some highly ferruginous red clay, which might be used in combination with other clays for producing various tints in terra cotta ware.

Near Umaria.

The existence of white clays in the Upper Gondwána beds of the Umaria region was first brought to notice by Láll Hira Lál, of the Geological Survey. In 1883 he reported their occurrence in large quantities on a hill one mile west of Amdári, a village 15 miles to the westward of Umaria, and pointed out their perfect similarity in appearance to the clay of Jabalpur.[2] Near the base of the hill, three quarters of a mile west-south-west from Baroudi (11 miles west of Umaria), about 40 feet of white clay and earthy sandstone is exposed. Here, as at Amdári, the clay is protected from denudation by a covering of Lameta limestone. Again, in the Mahanaddi, west of Chandia, beds of white and grayish-white clay or shale are intercalated with the Jabalpur sandstones. They are exposed on both banks of the stream for a distance of more than a mile at least, the principal seams being 4 or 5 feet thick. Such clays, indeed, are amongst the most characteristic beds of the Jabalpur group, and there can be no reasonable doubt that, if looked for, they would be found abundantly in many other places besides those mentioned. The most likely position to find them in is at the edge of (beneath) the Lameta limestone, and, for use at Umaria, search might be made where that group is exposed to the south of the station. It is to be recollected, however, that owing to the unconformity of the two groups, the limestone in many places has no clay beneath it, and that where the latter does exist it is often concealed by superficial soil washed down the slopes of the hills.

Small bricks made of the Amdári and Mahanaddi clays gave results similar to those made from the clay of Jabalpur in respect to contraction and colour. They were found to vary somewhat in their capacity for withstanding heat; some samples were quite infusible, while others softened slightly at a white heat. Although none of the Jabalpur clays that were tried yielded in this way, I apprehend that more extended experiments would show that such less refractory clays exist.

All the clays described above are of Upper Gondwána age. In 1886, however, Mr. Reynolds, then Deputy Manager of the Colliery, sent us specimens of a grayish-

[1] *Vide* page 146. The clay is often more or less laminated, so that it is difficult to draw the line between it and shale. The latter term is used in the section alluded to.

[2] Volume XVI, page 114.

white Barákar fire-clay,[1] which outcrops in the railway cutting, about 200 yards from the station towards the Colliery. The same stratum was passed through in sinking all the wells in the vicinity, the thickness being 3 feet, more or less. A sample of this clay, treated in the same way as the preceding, was found to be quite infusible, and to produce a whitish brick.

The 6-foot seam of coal includes a 'parting' of dark-gray shale, averaging 10 inches in thickness. This is separated from the coal by picking, and many thousand tons have accumulated on the spoilbank near the pit's mouth. It contains a good deal of pyrites, and does not look very promising as a fire-clay, but still, as it is to be had in such abundance for nothing, the point was worth examination. A sample, recently received from Mr. Maughan, Manager of the Central Provinces State Collieries, has been tried, both in its natural state and after burning off the carbonaceous matter. The results in both cases were unsatisfactory, and did not give much hope that the material could be turned to practical account.

FELSPAR.

In the area with which we are concerned, the metamorphic rocks, consisting as they do almost entirely of gneiss, are those in which all the available felspar is contained. As a constituent of the gneiss itself, as well as of the Jabalpur granite, felspar is ubiquitous, but in this form it is crystallized on too small a scale, and too intimately mixed with the other components of the rock to be of any use. The largely crystallized felspar, which is of value for pottery purposes, is found in veins of pegmatite by which the gneiss is traversed. These veins are of a highly irregular, strangulated character, running usually parallel, or nearly so, to the foliation of the gneiss, but sometimes obliquely to it. Many of them are several yards wide, but the thickness varies greatly and rapidly, and few of them can be traced for any great distance longitudinally. This, however, is of little consequence practically, as any want of continuity in the individual veins is amply compensated by their number.

The pegmatite is composed of flesh-coloured (or occasionally white) orthoclase or microcline felspar, and quartz, with very commonly a small proportion of schorl or mica, or both. In the best veins these latter minerals are nearly or quite absent, and the amount of quartz is so small that the rock is almost pure felspar, which would be easy to split up and quarry owing to the cleavage planes being several inches long. In other veins of an inferior character the proportion of quartz, &c., is greater, and the felspar crystallized on a smaller scale, while some veins, again, are worthless from excess of non-felspathic minerals.

Jabalpur District.

The granite which occurs in the neighbourhood of Jabalpur, extending for some 12 miles from south-west to north-east, and which is noticeable from the manner in which it weathers into piles of huge rounded masses, does not appear to contain any veins of pegmatite.

The metamorphic area nearest to the station is that which runs in a north-easterly direction from Sundarpur towards Dhumdhuma. In two traverses of this area I

[1] In speaking of the Barakár material as fire-clay, I would not be understood as implying that the Gondwána clays are not capable of being applied to the same use. The experiments detailed above show that most of them are highly refractory.

observed no pegmatite, but in the light of what I subsequently saw further east, I regretted not having made a more detailed examination, and circumstances prevented my returning for the purpose. In the event of pottery works being established at Jabalpur, it would be well to re-examine these rocks, which could be most advantageously done from Bhaunraha, by searching the beds of the different branches of the Barnu and Didula rivers, where they flow over the metamorphic formation.

Some good pegmatite was noticed in the crystalline area south-west of Silondi, but not in any quantity. The rocks, however, are greatly obscured by alluvium, and it is very probable that there are thicker veins than any I met with.

Pegmatite is plentiful in a small stream (or rather water-course, quite dry on 21st February), which joins the Sua naddi on the right (north) side, about half a mile south-east of the deserted village of Singrampur, and 2 miles east of Silondi. From the mouth of the stream for, say, half a mile up, numerous veins are met with, varying from 1 or 2 up to 5 feet in thickness, and the bed of the water-course is strewn abundantly with loose lumps of every size up to 2 or even 3 feet in diameter. In a small tributary of this stream veins are equally common. The pegmatite is composed almost entirely of flesh-red felspar with large cleavage faces, and quartz. The latter mineral is always very subordinate, and in many of the veins the rock is practically pure felspar. The mineral is fresh and undecomposed, although the gneiss in which it occurs is soft and rotten, so that the veins could be easily worked. A large supply could be obtained from them, and from the loose fragments. I have little doubt that pegmatite is equally abundant in other places within the same crystalline area, and it is to be regretted that the position is so far from Jabalpur—over 30 miles by the direct road, which is very bad for carts in the portion between Bagaráji and Sundarpur.

Near Umaria.

Pegmatite veins are of common, and in many places of profuse, occurrence throughout the gneissose area which extends from the Mahanaddi eastwards to near Umaria. It is unnecessary to describe those in the western part of this area, firstly, because they are generally inferior as a source of felspar to those further east, and secondly, because felspar is to be had in abundance close to the railway. Thus on the right bank of the Narsára naddi, just below the railway bridge, there is a vein 40 feet thick, in which there is not much quartz, and little or no schorl or mica. A very large supply of felspar could be obtained there. A considerable amount could also be procured at the eastern end of the hill, ⅓ of a mile north-north-west of Majgama; and in the railway cutting north of this village, between the 32nd and 33rd milestones, several veins are exposed in section, the largest of which are 2, 3, and 5 yards thick. Many other localities might be mentioned, the veins being so numerous as to furnish an inexhaustible supply. But those just noticed, which are close to the railway, and within about 4 miles of Umaria, are not likely to be worked out for many years to come. It is very probable that by searching the hills south of Koilári felspar might be obtained within an even shorter distance from the station than that just mentioned.

STEATITE.

As this mineral, in admixture with fire-clay, is said to form the material for fire-bricks of a very refractory kind, reference may be made here to the steatite

which occurs in pockets through the dolomite of the Marble Rocks. It is described in more detail at page 64 of the present volume.

QUARTZ.

Flint.

Although nodules of flint are known to occur in India,[1] similar to those of the English chalk formation, which are so largely used in the home potteries, none such exist in the Jabalpur district, or anywhere near it. The nearest analogues from a geological point of view, that is to say, with reference to mode of origin, are the cherty bands which occur in the Lameta limestone and transition dolomites. Those in the first-named formation are very irregular, the chert and limestone often interpenetrating, so that even if the former were sufficiently pure, and otherwise suitable for pottery, it would be difficult to extract it, and to obtain it free from carbonate of lime. The siliceous layers of the dolomite vary in mineral character from dark chert, through flint, to white translucent quartz indistinguishable, in hand specimens, from ordinary vein quartz. But the same objections apply as in the case of the Lameta chert.

Chert.

Chalcedony.

The qualities which render chalk-flint suitable for pottery purposes are its freedom from a deleterious amount of iron or other impurity, and the fact that calcination renders it so brittle that it can be readily ground to the finest powder. Both these advantages are shared by the chalcedony which occurs so abundantly, in geodes and nodules, through the Deccan trap. Like flint it becomes white, opaque, and easily crushed, after being calcined at a red heat.[2] A large quantity could be collected off the surface of the trap in some areas, while in other places the mineral is comparatively uncommon. But it is in the beds of the larger streams, flowing from the trappean region, that the most ample supply is to be obtained, and there is the further advantage that the pebbles are washed clean, so that the selection of the purest chalcedony is much facilitated. The main constituent of the river gravel in the Narbada, where it passes to the south of Jabalpur (about 5 miles distant) is trap, but next to it chalcedony is most abundant, the other pebbles met with being rock-crystal, jasper, and other varieties of Deccan trap quartz, with a few of zeolite and of vein quartz.[3] A large quantity of chalcedony could be collected, and, as the gravel is re-sorted every rains, when the river is in flood, the supply would be unfailing. Some rock-crystal is associated with it, often in the same geodes, but this mineral also becomes opaqne and brittle after calcination.

Besides the loose gravel just mentioned, there are some gravel beds intercalated in the alluvium, and exposed in the river-banks. But as the pebbles are of the same character, and do not include a greater proportion of chalcedony, these beds could not be profitably worked.

[1] In the Trichinopoly district, for instance, and near Sakkar and Rohri, on the Indus (Manual, Geology of India, pt. IV, p. 74).

[2] The disintegration in both cases is probably due, in a great measure, to the substance being a mixture of crystalline and (more or less hydrated) amorphous silica.

[3] These last doubtless come from some small area of gneiss; one pebble of the latter rock was observed.

Chalcedony is also obtainable in the same way from the Mahanaddi, the most convenient portion of the river for collecting it being that west of Chandia, the first railway station from Umaria. Although the mineral is decidedly less abundant than in the Narbada, I think there would be no difficulty in obtaining a sufficient supply. But more care would be required in collecting it, owing to the numerous pebbles of vein quartz, from the metamorphic rocks, which are also mixed in the gravel.

Vein quartz.

Beautifully white vein quartz occurs in both the transition and crystalline rocks, and would afford an exceedingly pure form of silica, were it not for the difficulty of crushing and grinding it,—a difficulty, however, which is diminished by calcination. Such veins may be seen in the mica schists of the Narbada below Lameta Ghát; there is a strangulated mass just west of the railway, $1\frac{1}{2}$ miles north of Chota Simla Hill; and they are very common in the gneiss near Umaria. The ballast used on the line about there is mostly quartz of this kind.

Quartzose sandstone.

Quartz sand.

Some portions of the Jabalpur sandstones are composed almost entirely of quartzose grains, with some felspar, and very little iron, and are therefore nearly white in colour. The sand derived from the disintegration of such rocks is naturally highly quartzose, and, being free from much iron, might perhaps be found capable of utilization in connection with pottery; as an ingredient of fire-bricks for instance. A sample of glass was made from sand of this kind, in the laboratory, but although the greenish tinge, due to iron, was not very pronounced, it was still too marked to allow of such glass being used for any but very common purposes.

COLOURING MATERIALS.

As colouring materials for pottery, it is unnecessary here to do more than allude to the manganese oxides, and manganiferous hematite, of Gosalpur, and the iron ore of Jauli, Sarroli, Agaria, and other places, as these have been fully described in previous volumes of these Records.[1]

LAMETA COAL.

The publications of the Survey do not appear to include any notice of this coal beyond the mere mention of its occurrence;[2] hence it may be well to place on record here the details of a section which has been exposed by recent workings. The quarry is situated near the right bank of the Narbada, at the bend of the river south-south-west of Lameta village, and about 9 miles west-south-west from Jabalpur.

Descending.	Ft.	Ins.
Surface (alluvial) clay, about	25	0
Pale gray, whitish, and yellowish shale, with some sandstone, about	12	0
Carbonaceous shale	0	2
Soft sandstone	1	0
Coal	0	2
Gray shale	0	2

[1] Vol. XVI, pp. 94, 116; Vol. XXI, p. 71.

[2] Memoirs, G. S. I., Vol. X, p. 142; Manual of the Geology of India, pt. I. p. 215.

Descending.	Ft.	Ins.
Coal	0	2
Gray shale	0	3
Pale gray shale	0	3
Soft sandstone	0	10
Coal	0	7
Gray shale	0	2
Coal and *Coaly shale*	1	0
Light gray shale	0	6
Coal	0	8
Gray shale (seen)	0	7

The seam, therefore, is 2 feet 11 inches in thickness, of which 2 feet 3 inches is coal, divided into three bands by two partings of shale which aggregate 8 inches. The least depth of overburden in the quarry is about 30 feet and the greatest 40. The excavation had been just abandoned when I saw it, and a new one was being sunk alongside (in contact with) it. The overburden, however, will be still greater there, owing to the dip of the coal at about 15° towards the south-east.

On the opposite bank of the river another quarry was being worked. The section exhibited 13 feet of Lameta limestone, resting uncomformably on about 15 feet of shale and sandstone, of the same character as in the last section. Beneath was the coal, but owing to its forming the floor of the quarry, and being partly flooded with water, the details were not ascertainable. The seam dips here towards the south-south-east at 5°.

The coal, as seen in both quarries, and also in a heap of several tons stacked near the latter, was very poor stuff. Some layers are good enough, consisting of bright jetty coal, breaking with a semi-conchoidal fracture, but these are interbanded with a very large proportion of shaly coal and carbonaceous shale. There is also a considerable amount of pyrites present. A picked sample (above the average) gave, on assay by Mr. Blyth.

Moisture	12·28
Volatile matter, exclusive of moisture	30·28
Fixed carbon	37·28
Ash (grayish-red)	20·16
	100·00

The coal was being used for brick-burning at Jabalpur. I should have supposed that it would be cheaper to get small-coal from Umaria, or Mopáni, than to work such a thin inferior seam, with such a depth of overburden. Although of course there is a *possibility* that the coal may improve towards the deep, there is no reason to anticipate that it will, and even if it should, perchance, do so, it would be necessary to working by mining, which would involve skilled superintendence, and an expense which the results likely to be obtained could scarcely be expected to cover.

It may be noted here that coal, on approximately the same horizon, was found at a depth of 70 feet, in a well in the old jail compound at Jabalpur.[1] It is not necessary to remind geologists that the Lameta coal is in the Upper Gondwána strata (Jabalpur group), and is therefore quite distinct from, and younger than, the Barákar

[1] Memoirs, G. S. I., Vol. X, p. 142.

coal of Umaria and Mopáni. It differs from the latter in the jetty appearance of the purer layers, and, as the above-quoted assay would seem to indicate, in the large proportion of water it contains.

RELATIVE ADVANTAGES OF JABALPUR AND UMARIA.

In comparing the relative advantages of Jabalpur and Umaria, with reference to the supply of the raw materials, it may be noticed that the Gondwána clays are to be had on the spot at the former station, while chalcedony can be obtained within 5 miles. But, on the other hand, felspar is not known to occur within the district nearer than Selondi. Should it be proved not to exist in the crystalline area north-east of Sundarpur, it would be necessary to bring it from Umaria, whence also, or from Mopáni, coal must be procured.

Turning to Umaria, the Gondwána clay is known to occur within 12 miles, and there is a considerable probability that it would be found much nearer if looked for. While coal and fire-clay are to be had on the spot, felspar is obtainable within 4 miles or less, and chalcedony may be collected in the Mahanaddi near Chandia, the first railway station from the colliery.

But the question is already beyond the range of discussion. Since the greater portion of these notes were written, Messrs. Burn and Company, who have, I believe, experimented most successfully with the Gondwána clay at their Ránigunj potteries, and who have for some time past entertained the idea of starting pottery works in the Central Provinces, have finally decided on Jabalpur as the site, and have been granted land for the purpose. To Mr. Glass it must be a source of gratification that his exertions in bringing the Jabalpur clays into notice are about to lead to so satisfactory a result.

ERRATA.

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA, VOL. XXII.

PART I.

Page 57, line 14 from top: for *have* read *had*.
" 57, " 3 " bottom: for *thusgi* read *thurgi*.
" 58, " 2 " top: for *have* read *had*.
" 58, " 9 " " " *flaviventus* read *flaviventris*.
" 58, " 10 " " " *teetum* read *tectum*.
" 58, " 11 " " " *flaviventus* read *flaviventris*, and for *teetum* read *tectum*.
" 58, " 8 " bottom: for *thusgi* read *thurgi*.
" 58, " 4 " " " *flaviventus* read *flaviventris*, and for *teetum* read *tectum*.

PART II.

Page 137, line 19 from top; *for* "less of" *read* "of some".
" 138, " 15 " bottom; *erase* "it".
" 139, " 15 " " *for* "screen" *read* "scree".

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1889. **[August.**

Abstract Report *on the* Coal outcrops *in the* Sharigh Valley, Baluchistan, *by the Director, Geological Survey of India.*

Mr. E. J. Jones has examined the whole of the system of valleys between Kach and Spintangi traversed by the Sind-Pishin Railway, on the Harnai route; and the conclusion he has come to, and in which I now thoroughly concur, whatever may have been my expectation regarding the immediate neighbourhood of Sharigh, is that the Khost locality is the most promising, and the one which consequently should be thoroughly tested by the mining exploration now going on under the superintendence of Mr. Morris.

Details of Outcrops.—The outcrops, taking them from Kach east-north-eastwards as far as Sunri, are:—

(1) Just south of Mudgorge Railway Station and below the conspicuous limestone band on the face of the hill. Thin seams of coal are seen at three places in the neighbourhood, the best of these having an aggregate thickness of about 2 feet, generally much crushed. At one of these places, where the coal has been dug out, there is 1′ 10″ of good coal; from which about 1,000 tons might be extracted.

(2) About 3 miles to the west of Dirgi Station: inferior coal, thickness 1′ 6″; and again at another place 1′ of coal. Dip very high. Also many other very thin seams or strings.

(3) Near Khila Hakim Khan, about a mile from the railway, coal can be traced for about ½ mile along the face of the hill. Headings have been driven in this coal to test its quality and mode of occurrence. Near centre of line of outcrops there are 2′ of coal, of which 11″ are jetty coal; and another giving 1′ 2″ of flaky coal. At the south-east end of section, the two seams just mentioned seem to occur in thicknesses of 10″ and 1′ respectively. On the whole, the thicknesses of coal are very variable; and, leaving the distance from the railway out of consideration, this does not seem a favourable locality for working.

(4) The next marked outcrops are on the hill face, a little south of west from the Khost rest-house. Landslips obscure the succession, but coal is

seen in five seams: coal and shale (mostly shale) 6′; good bright coal 1′; coal 9″; coal and shale mixed 2′ 2″; coal 3″.

(5) The next locality is the neighbourhood of Khost Railway Station, concerning which details will be given further on.

(6) North of Khost, and near to Haji Kats; very thin seam of coal, much crushed.

(7) Khila Ali Khan, 2 miles south-east of Khost; coal, probably extensions of the Khost seams (interval obscured by landslips), exposed along hill-side. Much crushed; often crushed out altogether, or squeezed laterally until in places it looks to be 6 or 7 feet thick.

(8) A short distance beyond the bridge at telegraph pole 210—4, there is an exposure of 1′ to 1½′ of coal dipping 60° north-east.

(9) In the hill to south-west of Sharigh; a one foot seam of coal, above which, with intervals of sandstone, comes another seam of 6″, and then a third of 1′ which however ultimately thickens into two of a foot each with 4′ of shale between. The valley between this and the main hill is full of contorted and vertical shales and sandstones, among which lie the layers of coal worked for local purposes at Sharigh. These are, however, mostly under a foot in thickness; while they are not fit for anything but surface workings. They are besides, some 3 miles, by path, from the Railway. The best seam, which is 2 feet in thickness, might be worth exploiting provided Khost were worked out.

(10) About a mile from the station of Sharigh, along the military road to Sibi (between the 75th and 76th miles from Sibi), there are some low hills of shale, giving four thin seams of coal; below which, to the north of the road, is a 4′ seam. Though the locality is very convenient, the dip of the coal is high, and it is situated in a region of much stratigraphical disturbance.

Beyond the Sharigh neighbourhood and on towards Nasik (Nakis) by Harnai, there are frequent outcrops showing several thin seams or layers of coal; but these are all generally so thin, or so rolled about in repeated folds, while any horizontal intervals are so short and few, that the prospects of any workable coal being found in this part of the country are altogether too unfavourable to justify exploitation as long as the prospects of Khost, or even Sharigh, remain.

General mode of occurrence of coal in Baluchistan.—From what has been stated so far, it is clear that here, in the Harnai valley system, there is a belt sometimes very well exposed, oftener not so well exposed, much twisted or folded over a good part of the country, repeated by dislocation, and very seldom lying in a flat way, of very thin seams of coal; one or even two seams of which appear however to be tolerably persistent in the Khost region. This is the general style of the thickness of the Eocene or Tertiary coal in the Baluchistan country, and indeed in the Punjab also and notably in the Salt Range: and were it not that our Railway system has now been brought into close proximity with these coal outcrops, they would never have been thought of as worth working except for the rare local requirements which might arise in such inhospitable regions. As it is, even now that railways have run alongside or across these coal outcrops, it still remains a question whether coal of such thickness can be profitably worked.

Certainly, it has yet to be shown that the original views of the Survey with regard to the capabilities of the Salt Range coal need be at all altered or qualified.

The problem before us is not so much:—can two feet, or even 1 foot 6 inches of coal be profitably worked; as:—are the conditions attaching to this occurrence of such thin seams such as shall not militate against their profitable extraction? Sir Warington W. Smyth, in his "*Rudimentary Treatise on coal and coal-mining*," writing of the Bristol and Bath District, says:—"It is observable that the *mode of working adopted* in the southern part of this district, *coupled with certain advantages*, has rendered it possible to work coal seams of little more than one foot thick; nay, in one of the little veins, I have measured the height to be only 11 inches of coal."[1]

The first drawback in the working of the Baluchistan coal—thinness being characteristic—is the uncertainty of the continuity of the seams. The next is the awkward lie: the dip being seldom low enough to allow of the coal being extracted according to ordinary methods; while the deeper one goes in the seam, the more laborious, as a rule, the extraction becomes.

These drawbacks are reported by Mr. Jones as being least developed in the Khost region; in fact, in the very field which has so far been experimented on by the North-West Railway Administration: so it is clear that all well-considered efforts must be directed to that exploitation.

The Khost seams.—The coal or the carbonaceous shale outcrops of Khost occur in the slope of the hill range a short distance to the south-west of, and running tolerably parallel with, the line of railway.

There are traces of several outcrops of more or less carbonaceous seams, some of which are merely repetitions displayed in surface slips; but a particular seam of coal has been traced longitudinally, or along the strike for nearly two miles, the absolute longitudinal continuity of which for the entire two miles can scarcely be questioned. We only know of its continuation on the dip, that is down at an angle of 50° or so into the body or mass of the hill range, by its occurrence on the spurs and in the small valleys between; or by the drifts, adits, and headings which have been made from time to time in the half-hearted way in which exploration or working has hitherto been conducted, though improved search has lately been adopted. There seems little doubt, however, that the coal extends into the hill to a considerable depth even below the level of the railway valley.

One good, though thin seam.—The seam to be exploited consists of two layers of coal, the upper being 10 inches thick, and the lower 1 foot $4\frac{1}{2}$ inches on the average, with a layer of from 2 inches to 1 foot 4 inches of shale between. In other words, the seam may be said to be *one* having an average thickness of 2′ $2\frac{1}{2}$″, with a band of shale; the minimum thickness of coal being 1 foot 8 inches, and the maximum 3 feet $3\frac{1}{2}$ inches.

The dip, or inclination, near the outcrop is very variable, being from 15° to 50° south-westwards: the variations are, however, due to local straining or bending from the weight of the superincumbent rocks along the outcrop; the true dip being about 50°.

Some 50 headings or drifts have been put down in the coal from the outcrop;

[1] The italics are mine.—W. K.

besides 4 adits which have been driven in from the face of the hill-slope to meet the coal at various points.

There is no reason to fear that the coal will fail before reaching the level of the river (in the railway valley); and judging by its constancy along the strike at the outcrop, scarcely any apprehension need be entertained of its failing for another 500 feet of vertical depth, beyond which it perhaps may die out. It must always be remembered that this occurrence may be merely the remains of a large patch of coal; and that thus though it is 2 miles or more in length, it may be only narrow and have only moderate width.

This, of course, can only be settled by continuing one of the headings well down to the deep: boring will not do, and workable coal will always be procurable from such a heading. At the same time, nothing certain can be said as to the probable area of coal until such a heading is driven.

If, however, the coal do continue to the deep for 1,000 feet along the dip, we may form such an estimate as the following. The coal retaining an average thickness of 2′ 2″; and taking 79℔ of coal to the cubic foot, 28·35 cub. ft. = 1 ton: there should be a total of 22,872,960 cub. ft. or 806,806 tons. Deducting 30 °/₀ for waste, we get 564,764 tons of available coal, or say 565,000 tons; a quantity not to be treated lightly in a country like Baluchistan, where fuel—barring the possibilities of petroleum—is so scarce.

Besides this, there are indications of another seam a few feet above that described, which however needs further exploration.

The following assays of the coal have been made at various times:—

KHOST COAL.

	Close to outcrop.	NEAR OUTCROP.		Lower layer, bottom of present working.	Upper layer, bottom of working.	Hitch, *i.e.* crushed coal.
		Upper layer.	Lower layer.			
Moisture . . .	2·98	2·20	1·72	2·30	1·80	2·70
Volatile matter . .	42·08	36·50	45·63	43·80	39·30	41·70
Fixed Carbon . .	45·48	50·27	48·40	45·50	39·80	49·60
Ash	9·46	11·03	4·25	8·30	19·00	6·00
	100·00	100·00	100·00	99·90	99·90	100·00

The coal contains a large quantity of pyrites; and this, as well as the shaly partings, or layers, will have to be removed by some sifting or washing process.

The coal makes an excellent coke; and though there is a large loss in weight (40 to 50%) the heating power is much improved and, weight for weight, much more work can be got out of the coke than from the untreated coal.

A special advantage lies, last of all, in the fact that this coal is in comparatively close proximity to the line of railway.

Profitable working still doubtful.—Nevertheless, the problem remains as to whether the coal extraction is to be continued on that simple and certainly ready

method of grubbing it from the outcrops on the face of the hill slope to the south of the railway line, which method can of course only last for a short time; or that it should be worked by a necessarily very expensive system of permanent and progressive colliery operations.

The subject, however, of the most advantageous form of working such a coal-field is one on which I refrain from offering an opinion, however much my own training as an engineer and experience of the *entourage* and structure of collieries, as well as that of other officers of the Survey, may qualify this Department for such discussion. I would, however, relying on the experience gained in this exploitation, go so far as to say, and I do so advisedly, that it is extremely doubtful whether this work can be carried one stage further with the staff employed at present.

Within the last year, the exploitation has been carried on by a (presumably certificated) miner from England, of good experience in coal-fields of the regulation type at home; but ill-adapted for co-operation with an Executive Engineer in charge who is not a specialist at colliery work. The miner is very badly paid (R150 a month, I think). The Executive Engineer is only on the spot at intervals, he having in fact to look after Khost, Dandot, and the coal outcrops away beyond Rawalpindi.

I say emphatically that the working of such a field, if it is not to be a failure, must be entrusted to a Colliery Superintendent of experience in high-dipping coal, with a good English miner under him.

It would be of the last importance also that the final judgment as to the systematic mining of the field, or its abandonment, should wait an inspection and report by Mr. Maughan (Central Provinces Government Coal-fields) who is one of the few official colliery authorities with the Government experienced in high-dipping coals.

The problem of opening up this field or not is an exceedingly difficult one, requiring the gravest and most wide discussion: but it is not a new one, because we have the experience gained at the Dandot Colliery in the working of a thin seam of coal of the same age. On that experience, such as I know of it myself, I can say that though the promise held forth by the conditions of the Khost coal-field is not very encouraging, still it is more encouraging than that of the Dandot field ever was, or even now is; while the working of it will involve much less costly supplementary plant and machinery, and will be, above all, less dangerous.

WILL. KING,
Director, Geological Survey of India.

June 1889.

Note *on the* Discovery of Trilobites *by* Dr. H. WARTH *in the* Neobolus beds *of the* Salt-Range; *by the* Director, *Geological Survey of India.*

On the 15th January last I received a letter from Dr. Warth, informing me that among very many specimens of other fossils which he had found in the *Neobolus beds* during a late excursion in the Salt-Range, and which he had then just forwarded to Dr. W. Waagen at Prague, were some rock specimens with shells and three minute

fragments which he suspected were possibly Trilobites. He had so little expectation of finding such organisms that, only when he got back to Dehra and had looked over the collection, did the suspicion arise that he had perhaps after all got them. The exact *habitat* of the fossils will of course need confirmation by other finds; but Dr. Warth's conviction, which need scarcely be doubted, is that they were from the Neobolus beds.

This was so interesting and remarkable a discovery, where we had so long looked on those beds as of Silurian age, even though this age had been strongly contested and, in point of fact, had been virtually decreed against by Dr. Waagen in the Preface to the first volume of the "Salt-Range Fossils"; that we could only wait patiently for the Salt-Range Palæontologist's opinion.

In due course Dr. Waagen's letter arrived, wherein he writes:—"The Trilobites have now arrived from Dr. Warth, and I see that there are two determinable species. One is a *Conocephalites*, very nearly related to *Con. formosus*, Hartt. from the St. John's group, and the other is probably an *Olenus*. The beds in which such forms occur cannot be anything but Cambrian, and they must probably be classed as referable to the upper region of the Lower Cambrian."

I should indeed have preferred that Dr. Waagen had announced the discovery himself in a preliminary paper for these Records, as was done in the case of the find (1886) of *Conulariæ* and other fossils in the Boulder-bed[1]; but his desire is that the subject be discussed in all its bearings in forthcoming parts of Vol. IV of the Salt-Range Fossils, now being prepared for publication. There will be some delay in the appearance of these parts; so, rather than that there should be any further holding back of the news of this discovery, or of Dr. Waagen's preliminary treatment of its bearings on his "geological results," as they are to appear in the Palæontologia Indica, I take the liberty of now giving the following extract from his manuscript:—

"In the Introduction to the first volume of the present work in 1879 I have introduced the following grouping founded on the *data* then available:—

UPPER SERIES. (Newer Mesozoic formations.)	10 Olive group. 9 Variegated group.
MIDDLE SERIES. (Ceratite beds.)	7 Ceratite beds.
LOWER SERIES. (Productus limestone.)	6 Lower limestone of Salt-Range. 5 Speckled sandstone. 4 Magnesian sandstone. 3 Obolus or Siphonotreta beds.
Not included in any series.	2 Purple sandstone. 1 Saline series.

"This can, however, no longer be retained, as several new facts have come to light which cause me to take another view of the matter.

"With regard to the Lower Series there has been detected in the meantime not only the great discordance which cuts just through the middle of the division; but, just while I write these lines, I have a letter from Dr. Warth announcing to me his discovery of Trilobites in the Neobolus beds—specimens which seem to be very nearly related to *Conocephalites*. Thus, it is no longer possible that the beds below the great unconformity should form one series with the more recent strata above the unconformity, which are of Permian and topmost carboniferous

[1] Rec. G. S. of I., Vol. XIX, p. 22.

age; and therefore the 'Lower Series (Productus-limestone)' of former times will have to be cut up in two.

"Such a proceeding has been advocated already by Mr. Medlicott, and in fact Mr. Wynne always termed the Neobolus beds 'Silurian.' His reasons, however, for so doing were restricted to the statement of Dr. Stoliczka and myself, that the Neobolus beds contained '*Obolus* or *Siphonotreta*.' As soon as the *Obolus* or *Siphonotreta* disappeared, there were no further reasons for considering these beds as Silurian.

"When I commenced the description of the Salt-Range fossils, there were the following data as to the age of the Neobolus beds at my disposal:—

(1) The lower limestones of the Salt-Range, that had been considered as carboniferous by Mr. Wynne, proved to be of Permian age.

(2) That the *Neobolus* beds followed a few hundred feet below the Permian, without any trace of an unconformity, was admitted by Mr. Wynne. In point of fact, there seemed to exist a perfect transition from above downward.

(3) In the Magnesian sandstone, following immediately above the *Neobolus* beds, and being most intimately connected with them, the specimen of *Sigmodus*, described in Volume I of the present work, had been found, which certainly nobody would expect to collect in lower, or even upper, Silurian beds.

(4) Specimens and drawings of the *Obolus*-like fossils contained in the *Neobolus* beds were shown by me to Statsrath Valerin-o-Möller of St. Petersburg, now in Tiflis, and later on to Mr. Davidson of Brighton; and both declared most decidedly that there were no forms among them identical with things hitherto described out of Cambrian or Silurian beds, and Mr. Davidson especially advised me to make new genera out of these things.

(5) At last there was collected by my own hands a fossil in the *Neobolus* beds which is to all appearance a *Fenestella*, with large fenestules—a form which had never been observed previously in beds lower in the series than carboniferous.

"All this combined to cause me to consider these beds as probably of lower carboniferous age. After Mr. R. D. Oldham, however, had proved the existence of a great unconformity, the matter appeared in a new light, though the existence of the unconformity alone was not sufficient to settle the age of the *Neobolus* beds. Nobody in the world could have put forward the opinion that beds on which Permian and topmost carboniferous were unconformably deposited, could possibly be equivalent in age to the mountain limestone, but had necessarily to be considered as Silurian. Therefore I hesitated, even after Mr. Oldham's discovery, to give up an opinion to which all available palæontological data seemed to point, and thus I reiterated in the Preface to the 1st volume my formerly-expressed opinion, that the *Neobolus* beds were of lower carboniferous age.

"Nevertheless, the case seemed to be worthy of further investigation, and seeing that it was impossible to arrive at any better results as long as no new data were forthcoming, I wrote to Dr. Warth, who was then in the Salt-Range, to search for more fossils in the *Neobolus* beds, at the same time indicating some localities where a close search would be most promising. Dr. Warth, however, was then prevented from making his investigations and for about two years the case seemed rather hopeless, when all of a sudden the letter from Dr. Warth arrived announcing his discovery of lower palæozoic *Trilobites* in the *Neobolus* beds. Now at last the truth seems to be arrived at, and the great unconformity now seems really to indicate a great break in the succession of strata in the Salt-Range.

"According to these considerations it seems now necessary to divide the lower series, formerly adopted by me, into two different series, though both be of palæozoic age; a lower palæozoic one, which will have to include all the beds below the great unconformity, and an upper palæozoic one, which comprises the beds above the unconformity and to which the name 'Productus-limestone' must be restricted.

"With regard to the middle series, the ceratite beds, no change seems necessary. The palæontological and stratigraphical data relating to these beds were already so clear and well settled when I commenced the present work, that any mistakes about their age or relations were excluded.

"The case is again different with regard to the upper series comprising the newer mesozoic formations. It has been stated above that the 'Olive series' of Mr. Wynne can no longer be retained, but that it is partly identical with his speckled sandstone, while the rest of it goes to form a new group for which I introduce the designation 'Carbonaceous group or *Cardita beaumonti* beds.' Whether this latter really has to be considered as of mesozoic age has become somewhat doubtful, and, therefore, I hesitate to include it again in the upper series.

"Thus we arrive at the following grouping, which, however, applies only to the large series. Within these series smaller groups can yet be distinguished, as will appear in the sequence. In order to give a general idea of the grouping of the rocks in the Salt-Range, I append a tabular view, in which I insert for general reference also the probable equivalents of the Salt-Range rocks with those of Peninsular India and of Europe, with the distinct proviso however that these equivalents must not be taken as definitively settled, but solely as the most probable ones as far as our knowledge reaches up to this moment."

Tabular view of the rock-groups represented in the Salt-Range, with indication of their probable equivalents.

Larger Series.		Rock-groups.	Probable equivalents. In Peninsular India.	Probable equivalents. Elsewhere.
		19 Nummulitic.		
?		18 Carbonaceous group (*Cardita beaumonti* beds.)	Deccan Traps (part).	
		Unconformity.	*Break.*	
Newer Mesozoic formations.		17 Dark green pisolitic sandstones (Neocomian).	Kachh.	Neocomian.
		16 Upper jurassic limestones.	Jabalpur.	Upper and Middle Jurassic.
		15 Variegated group.		Lower Jurassic and perhaps Rhætic.
		Overlap.		
Ceratite beds.		14 Grey and yellow dolomites.	? Rajmahal.	Trias. ? Upper.
		13 Grey bivalve limestones.	Panchet.	? Middle.
		12 Ceratite beds.		? Lower.
Upper palæozoic series (Productus-limestone).	Siliceous limestone group.	11 Upper Productus-limestone.	Damuda.	Permian.
		10 Siliceous limestone (Middle Productus-limestone).		
	Speckled sandstone group.	9 Lower Productus-limestone.		? Lowest Permian. or ? Topmost Carboniferous.
		8 Speckled sandstone.	Talchir.	
Lower palæozoic series.	Magnesian sandstone group.	*Unconformity.*	*Unconformity.*	Lower Palæozoic. (? Sinic formation. Richthofen: China, Vol. II.)
		7 Red shaly zone (Salt-pseudomorph zone).	? Vindhyan.	
		6 Magnesian sandstone.		
		5 Dark shaly zone (Neobolus beds).		
	Purple sandstone group.	4 Upper Purple sandstone (Purple sandstone).		
		3 Rock-salt and red Gypsum group.	Vindhyan.	
		2 Grey Gypsum group.		
		1 Lower Purple sandstone.		

NOTE.—Salt-Range Fossils, Vol. I, Pal. Indica, Ser. XIII.

Geological Notes *by* C. L. GRIESBACH, C.I.E., *Deputy Superintendent, Geological Survey of India.*

THE SEQUENCE OF FORMATIONS IN SPITI.

Under the title "*The* Sequence *and* Correlation *of the* Pre-Tertiary Sedimentary formations of the Simla Region *of the* Lower Himalayas"[1], Mr. R. D. Oldham discusses the sequence of rock systems not only of the Simla region, but also of the Himalayas of Kashmir and Spiti. This paper is followed by another,[2] in which Mr. Oldham, under the heading of "Spiti," describes also the crystalline groups of the country between Simla and the Babeh pass.

Mr. Oldham, when visiting Spiti, was *en route* to the Zanskar area I believe. His zeal to complete during a single season's rapid travels a complete geological reconnaissance of ground, which to study has required years of labour of more than one geologist, may partly account for the incomplete view of the geological structure of Spiti, which is revealed in the pages quoted.

Spiti is classic ground; it had been visited and described by our eminent and late colleague Dr. F. Stoliczka,[3] his published sections have been until recently considered crucial ones for the geology of the North-West Himalayas, and his nomenclature had been largely applied to the geological structure of other regions of the Himalayas. It would therefore have been well if Mr. Oldham had been able to afford more time for a careful study of the sequence of rocks of Spiti, in order to see in how far Stoliczka's first classification of rocks should be modified, and in how far the correlation of formations with those of other areas is admissible. I have myself no doubt, that had Stoliczka been able to revisit Spiti, he would have modified his views on some points, and would perhaps have recognized certain horizons which he had overlooked. My own work in the Central Himalayas was brought to a close in 1883 with the examination of the southern and eastern part of Spiti; but unfortunately, the publication of the results of my labours in those regions has been delayed owing to long periods spent in Afghanistan and on the frontier, and although now nearly ready for the press, it will be many months before it can be issued. I think, therefore, the preliminary sketch of the geological structure of the southern part of Spiti contained in the following pages may clear up some points which Mr. Oldham has left doubtful. I may mention here, that I possessed the great advantage when visiting Spiti, of having slowly worked through the sections of the high ranges of Kumaun, Garhwal and the adjoining portions of Thibet; so that I had no difficulty in tracing out all the rock-groups of the Central Himalayas in the Spiti area. This was all the more easy, since most of the rocks of the latter ground have yielded fossils, as all the formations in the eastern sections have done.

I entered the Spiti drainage by the Babeh pass, returning into the Sutlej valley by the Manirang pass. By doing so, I traversed the palaeozoic and the mesozoic groups, up to the upper rhætic system.

[1] Records, XXI., pp. 130 ff.
[2] Do., do., do. 149 ff.
[3] Mem. G. S. I., Vol. V.

Stoliczka's Sequence.—I have to differ in some few points from the original interpretation given by Dr. Stoliczka. He grouped the sedimentary formations below the jurassic "Spiti" shales into the following divisions:—

Upper Tagling	Lias.
Tagling limestone, Para do.	Rhætic.
Lilang Series	Trias.
Kuling Series	Carboniferous.
Muth Series (Upper), Babeh do. (Lower)	Silurian.

Trias.—I have little to say in this paper concerning the mesozoic rocks: the general grouping as shown by Stoliczka is according to facts, and I have only to add that the Trias (Muschelkalk horizon) does not rest upon carboniferous; but there is a series of beds, underlying the former conformably, ranging through the upper productus shales (Permian), the Otoceras (passage) beds and thin limestones with lower Trias brachiopods, which series comprises the lowest Trias (Bunter) of Central Europe, but reaching down even to the Upper Permian. The series is not of great thickness, but is well exposed both at Muth and in sections north of it (Kuling, &c.), but Stoliczka has apparently included it in the *Kuling beds*.

The chief changes which should now be made in the correlation and nomenclature of the Spiti formations concern the palæozoic group.

When I speak of silurian, carboniferous, etc., in these pages, I understand these terms homotaxially; though, as I shall endeavour to show later on in my full report in the Central Himalayas, the various marine systems are closely connected with those of Eastern and South-Eastern Europe.

The route descending from the Babeh pass down the Pin river, traverses a fairly good section of the entire palæozoic group, and I shall therefore describe it as it appears along this line.

Cambrian.—Babeh series, Stol. = Azoic, Strachey = Cambrian.—Between the metamorphic rocks south of the Babeh pass and the lower silurian exposed near Buldur (of the map), a thickly-developed system of rocks is seen, which I have identified with pre-silurian rocks of the Central Himalayas, called by General R. Strachey [1] *Azoic series*. The beds composing this system are conformably overlaid by the lower silurian; and this, coupled with the fact that it has not proved devoid of organic traces, has induced me to correlate it with the cambrian of other regions. The term "*Babeh*" system might have stood with some modification of its meaning, had I not already worked out the Central Himalayan pre-silurian rocks before recognizing in them Stoliczka's Babeh series. But, as under that name some members of the silurian have also been included, I prefer to retain also in this paper the term "Cambrian."

This rock system consists, in the Spiti area, of a succession of chiefly quartzitic rocks; I did not study it in detail, but found similarly as in the Garhwal sections, a purple semi-metamorphic quartzite predominant. Associated with it are silicious shales, and a largely developed conglomerate or rather boulder-bed which is a most characteristic rock, and traceable from Spiti to the Nepal frontier. It is such a

[1] Q. Jour. Geol. Soc., VII, p. 292.

constant factor in this system, that once seen it will always easily be recognized. In its constancy it reminds me of the ever-recurring boulder bed near the base of the Talchirs. These dark purplish quartzites and conglomerates form usually thick beds, and are associated with greenish talcose slates and semi-metamorphic schists which I found near the boundary of the gneissose series south of the Babeh pass, and again near the upper boundary of the system. In these same greenish schists, fossil traces (*Bellerophon ?*) were found in the Niti sections. Strata of thinner-bedded purple and brown silicious rocks are not absent, which also here show extensive and often very typical ripple-marking, quite distinct from the wrinkling into which the beds have been contorted.

Granite near contact with gneissic system.

As far as I have observed, the contact between the gneissic rocks of the south side of the Babeh pass with the overlying slates (Babeh series = Cambrian) is not sharply defined. Intrusive granite obscures the boundary, and it is most probable that it will be found to enter the slate series in the same manner as seen in the north-eastern extension of the belt of cambrian rocks seen near Shipki in Hundes, and further east in the Nilang area.

Extensive folding of strata.

The system shares in the extensive plication which has crumpled the entire succession of marine sedimentary rocks of this and the neighbouring sections of the Himalayas. The folds are generally very close, reversed flexures with their longer shoulders falling to the north and north-east.

Thickness of cambrians.

The thickness of the system I have not been able to ascertain, but it will probably be found to be not less than that of the cambrians of the north-eastern and eastern sections, where I estimate it as from 3,000 to 4,000 feet.

Buldur synclinal.

Near the camping-ground of Buldur (of the map), the beds form a deep synclinal, strike nearly east and west, enclosing a portion of the silurian system. Conspicuous from afar, a band of bright red to purple silicious shale shows the deeply-bent curve of the synclinal, and at the same time forms the lower boundary of the silurians. The streams which join near this camping-ground from the south-west have eroded through the synclinal at nearly right angles and so exposed the structure. Dark limestone, and above chiefly flesh-coloured quartzites, are inclosed in this synclinal; they form respectively the lower and upper silurian, which, however, are seen much better lower down the Pin river valley.

Palæozoic section south of Muth.

Between this synclinal and the village of Muth a perfect section of the palæozoic group[1] may be studied. The structure is simple, though the entire sequence of beds is a good deal folded. Down in the valley along which the road passes, little or nothing is seen. The track from the pass leads almost wholly over moraine matter, and over the enormous fans descending from the numerous small side ravines. The high and rugged ranges which enclose the valley have to be ascended before much of the true structure of the rocks can be made out. I think, on the whole, the range

[1] Mr. Griesbach uses the term 'group' throughout this paper in a way which is not accepted generally by English geologists. See *postea;* Notice of Presidential Address, Geol. Soc. Lond., p. 180.—*Ed.*

of hills forming the left side of the valley is perhaps the easier of the two, and enough of the beds forming it are exposed for the interpretation of the structure. I found it to consist entirely of palæozoic rocks, much crumpled; though, thanks to several very characteristic horizons, the structure is not difficult to unravel.

The southern end of the range is formed by the cambrians as already described; they are conformably overlaid by the silurian system, which occupies the central portion of the range, followed, near its northern extension, south of Muth, by the devonian and carboniferous systems. The enormous succession of formations between the base of the cambrians aud the upper carboniferous quartzites near Muth shows one conformable whole; with great variations in lithological character of its component beds, but no *sharply* defined boundaries anywhere, rather unmistakeable gradations from one into the other series of beds.

Unconformity.

The first break occurs above the upper carboniferous, upon which the black "Kuling" shales, with many *producti*, rest unconformably. This is the most important point connected with the structure of Spiti as will be seen later on.

Sequence of palæozoic divisions.—The divisions of the palæozoic rocks of the Pin valley are therefore as follows:—

With trias-rhætic resting conformably on:—

10. Black productus (Kuling) shales	. . . . . .	Permian.
Unconformity.		
9. Dark flaggy limestone	. . . .	Carboniferous.
8. White quartzite series (Muth quartzite)	. . .	
7. Red crinoid limestone	. . . .	
6. Earthy, dark-grey limestone	. . . . . .	
5. Hard, dark, concretionary Coral limestone with splintery shales	. . . . . .	Devonian.
4. Dirty flesh-coloured to brown quartzites alternating with grey and greenish shales	. . . . . .	Silurian.
3. Coral limestone series	. . . .	
2. Bright red quartz-shales	. . . . . .	Cambrian.
1. Slate, quartzites and conglomerate series, seemingly conformable on:	. . . .	
Gneissose Series.		

The divisions 1 to 4 correspond exactly with the silurian and pre-silurian sections of the Hundès and Central Himalayan ground. Fossils occur in nearly all the beds but they are not very well preserved, and I did not devote much time to the search for them in Spiti. The rocks are so characteristic, and the lithological similarity to the eastern section is so complete, that I could pass on to the carboniferous rocks without hesitation.

Red quartz-shales.

The red quartz-shales (2), are as constant a termination to the cambrians as in Kumaun and Garhwal, and although the thickness is only from 200 to 300 feet, the bright red tint of the bed marks the boundary as if with a red thread.

Coral-limestone.

The overlying coral-limestone (3) averages 300 feet in most sections, and consists principally of thin-bedded coral-limestone of dark grey colour, with occasional intercalations of silicious and shaly beds of greenish and pink colour. Near its junction with the red quartz-shales,

beds of dark (fossiliferous) coral-limestone alternate with the red shales, which are there often replaced by greenish-grey beds of otherwise similar lithological character. This alternation near its upper boundary would alone have induced me to include the quartz-shales (2) with the lower silurian, but the horizon seems more closely connected with the underlying quartzitic cambrians into which is passes gradually; so that I felt the red quartz-shales must rather be considered as structurally to belong to the underlying system. In the coral-limestone series (3) fossils are very commou, though fine specimens are not easily got out. Corals and brachiopods of lower silurian type are frequent.

Quartzite series.

This series passes upwards inio the flesh-coloured quartzite series (4), which is ever present in all the upper silurian sections of the Central Himalayas. The thickness of it may here be from 1,500 to 2,000 feet, though I am inclined to think that it will be found to be rather below this estimate in less disturbed sections. Within these crushed flexures jointing amounting often to considerable faulting, is so common, that a true estimate of thickness is not easy. The passage from the lower silurian coral-limestone (3) into this series is gradual: beds of dirty greyish flesh-coloured quartzite make their appearance between the dark coral-limestone low down in the latter series, increase in frequency higher up, until finally is developed a distinct series which is roughly characterized as being an alternation of flesh-coloured to brown often speckled quartzite and grayish-green shales with fucoid marks. The latter often show imperfect cleavage, and near the upper boundary increase in thickness. Fossils and casts of such are frequent throughout the formation; they are nearly all brachiopods; *Orthis sp.* and *corals* with types of the upper silurian are found throughout.

I believe that Dr. Stoliczka has rightly recognized this quartzitic series as silurian, fossils being common in it, especially on its weathered surfaces.

Descending the valley, he came up with the white quartzites near the village of Muth, which are further on overlaid by the black "Kuling" shales; and I think he must have believed that it and the silurian quartzite belonged to one formation.

But there is no silurian rock near Muth itself; and the white quartzite near that village is upper carboniferous, as will be seen further on.

Devonian limestone.

The upper silurian (4), is conformably overlaid by a thickness of from 700 to 800 feet of a very dark, hard limestone (5), concretionary in parts, alternating with dark splintery shales. This series also has a wide geographical distribution, from the Nepal frontier in Byans, where it attains much greater thickness, to Spiti, little if at all varying in lithological character and containing few fossils. I found none in Spiti, and those met with in the eastern section might either be lowest carboniferous or devonian. Studying it connectedly with the adjoining horizons, its geological position at the base of the carboniferous is apparent; and then the uniform lithological character of the horizon over an extensive area is striking, but little could be gained by simple lithological identification in the field unaided by a clear view of its geotectonic conditions. Almost identically, the same rock may be met with in higher horizons.

I think it is very probable that this same series extends far into Kashmir, as shown by Lydekker,[1] who places it in the carboniferous system. Lithologically simi-

[1] Mem. Geol. Sur. Ind., Vol. XXII, 1883.

lar rock occupies a carboniferous horizon in the Hindu Kush sections and in the prolongation of this mountain chain through North-Western Afghanistan and North-Eastern Persia, where it probably thickens out and runs into upper carboniferous. I am induced to correlate it with devonian rather than carboniferous; the fossils found in it in the Central Himalayan sections, as far as I have been able to examine them up to this, might be characteristic of either devonian or lower carboniferous, but its evident connection through passage-beds and alternations of strata with the underlying upper silurians indicate that at all events between the upper portion of the series (4) and the true carboniferous rocks (6 to 9) all intervening horizons from upper silurian to lower carboniferous must be included. Sharp boundaries there are none, and the whole represents an unbroken succession of deposits.

Carboniferous.

The carboniferous system is much more fully represented in the Spiti area than in the sections eastwards. Not only are the several series of formations composing it represented in great thickness, but the sequence of horizons is more complete than is the case in Garhwal and Kumaun. The divisions of the system in Spiti are as shown on page 161; the limestone (9) is wanting in all the eastern sections,—eroded I believe before the black *productus* shales were laid down on it. The lower boundary between this system and the underlying dark coral limestone (5) is not well defined.

Earthy grey crinoid limestone.

The lowest horizon which I take to belong already to the lower carboniferous is an earthy grey limestone (6) of irregular thickness and not very conspicuous. It might easily be altogether overlooked or considered part of the underlying coral-limestone (5), if I had not observed it in the Dharma section more amply developed. Here as there, it is characterized by the presence of crinoid remains, which are found throughout this and the suceceding division. The passage from this grey limestone into the overlying red crinoid limestone (7) is gradual, and the former seems altogether a local development only of the latter. Together, the two series may be from 600 to 800 feet in thickness. With the exception of badly-preserved *orthoceras* fragments, nothing but crinoid remains were found in this series; but the rock is so constant over the entire area of the Central Himalayas that a mistake is absolutely impossible. Its colour, a brownish red (Indian red), distinguishes it everywhere and often helped me in making out the structure of the upper palæozoics in mountain tracts which were only partially accessible to me. Its intense colouring, coupled with the fact that it is nearly invariably overlaid by the glaring white quartzite (8), serves as an unfailing guide in such cases. Besides the red cambrian quartz-shales (2), it is the only red formation: a patchy red bed occurs in the rhætic and a semi-metamorphic red bed amongst the nummulitic series, but with neither can the red crinoid limestone be confounded.

Red crinoid limestone.

White quartzite series.

It is overlaid by the white quartzite (8), the Muth quartzite of Stoliczka. This also is an old friend, met with in the Garhwal and Kumaun area, where I established its upper carboniferous age;[1] it seems one of the most widely distributed of Himalayan formations, for Mr. Lydekker has shown that it also occurs in Kashmir near the base of the Kuling shales.[2]

[1] Rec., XIII, p. 85. [2] Mem. Geol. Surv. Ind., Vol. XXII.

The junction with the underlying red crinoid limestone is well defined, although several irregularly intercalated beds of the latter are found in the white quartzite near the boundary.

The main mass of the series is formed of fine-grained white quartzite in thick solid beds; in its upper portion the quartzite becomes occasionally a silicious sandstone, and there are now and then some thin limestone beds intercalated in the more eastern sections. Near Muth village in the Pin river valley the total thickness of it is about 500 feet. Some fossil traces, chiefly of brachiopods, are found on the weathered surfaces of the rock, rarely in good preservation, and are indicative of the carboniferous age of the series.

Oldham has correctly correlated the Muth quartzite with the carboniferous white quartzite of Kashmir,[1] but he does not seem to have noticed the carboniferous beds which both underlie and overlie the formation.

Grey limestone series.

It is overlaid conformably by a hard, splintery grey limestone (9) in flaggy beds, of a total thickness of about 70 feet, which has yielded numerous fossils, though few in species. Amongst them are several *producti*, *Athyris royssii* and *corals*. Its evident connection with the white quartzite (8) and fossils define its upper carboniferous age.

Upper boundary of carboniferous.

Permo-trias.

The small ravine which descends near the village of Muth marks the upper boundary of the carboniferous system. The strata forming it are there seen to dip about 45° to 50° below the Permo-trias, forming a great synclinal fold between Muth and Tilling which is splendidly exposed in the hill west of Khar.

It will therefore be seen that the Spiti carboniferous, so far from being "*not well exposed*," [2] is well represented and even more fully than in the sections eastwards. If I had only seen the sections in Spiti, where the beds of the Permo-trias seem to rest conformably on the carboniferous, I would unhesitatingly have considered the small thickness of *productus* shales (10) at the base of the lower trias also as carboniferous. But I have traced this contact from the frontier of Nepal, from Byans through the entire range of the Central Himalayas to Spiti, and found that whilst the productus shales are never absent from the base of the trias, forming with it as it were one great system of beds, they overlap in succession the various horizons of the carboniferous system in the different areas. For instance, the Permo-trias rests on white quartzite in Dharma and Byans on an eroded surface of white quartzite; in other sections on red crinoid limestone in the Niti area; and here in Spiti on a limestone with carboniferous fossils not seen in the eastern sections. The inference therefore is that the Permo-trias represents one continuous whole, which overlaps the several horizons of the carboniferous, and that the contact is unconformable—in fact represents a break between the two systems. I can only again assert my conviction, strengthened by many observations all pointing to the same conclusions, that there are grounds for supposing that great physical changes have occurred in late carboniferous times, or at the beginning of the Permian era. I expressed this belief after my first examination of the Niti sections in 1879 in the paper above quoted.

Unconformability.

[1] Rec., XXI, p. 151-3. [2] *Ib.*

As I have already said, a great synclinal fold forms the belt between Muth and Tilling, followed by an anticlinal near the arch of which the village of Khar is situated. The ranges north of Khar to Dangkhar are a succession of more or less complicated flexures. The carboniferous rocks are therefore generally seen near the base of the ranges and in the valleys, whilst the higher cliffs are formed of the overlying Permo-trias. But the best section of the carboniferous, which I have so far seen, is the one exposed along the jagged ridges of the chains of hills on both sides of the Pin valley and south of Muth.

Synclinal north of Muth.

Near Muth village, and on both sides of the valley, I found above the upper carboniferous limestone (9) an unbroken succession of beds ranging from the Permian *productus* shales (10) to beds with *Terebratula gregaria* and *Rhynchonella austriaca* (Upper Rhætic); and, as I have already shown, this system of strata must be considered as being unconformable to those below. The trias with the permian productus shales at their base overlap the entire series of the upper carboniferous in the Central Himalayas; and I think therefore on stratigraphical grounds the division between the palæozoic group and the next following should in the Himalayas be made at the end of the upper carboniferous rather than the permian.

Permo-trias near Muth.

The permian productus shales (10) are about 150 to 200 feet in thickness, mostly densely black, crumbling and soft, divided by strings of ferruginous concretions and layers of splintery shales. Occasionally an irregular bed of dark grey to olive-coloured sandstone, weathering dark brown, divides the formation and is generally full of fossils, chiefly *producti*. The shales also yielded many specimens of *producti* and a few other *brachiopods*.

Permian productus shales.

These shales are evidently Stoliczka's typical Kuling beds. They are well exposed near Tilling, Khar, Kuling, and may easily be traced as a black band near the base of the hills north of Kuling. They again are visible in the Spiti river valley west of Dangkhar, below the wooden bridge above the junction with the Pin river. They yielded fossils wherever met and are invariably passing upwards into beds, which Stoliczka failed to distinguish. These are dark limestone beds alternating with black friable shales, of about 200 feet in thickness and closely resembling the productus shales below. But these beds have yielded, in all sections which I have hitherto examined, a fauna totally distinct from that found in the beds below. Numerous species of *cephalopods*, chiefly of *Xenodiscus*, *Otoceras*, and a little higher up of *Ceratites*, may be picked up. *Producti* have disappeared, and in the uppermost beds of the series *brachiopods* are found which I cannot distinguish from species found in the lowest trias of the Alps.

Otoceras stage.

Lowest trias horizon.

This succession of beds is well seen near Kuling, north-west of the village, where it is conformably overlaid by limestone with Muschelkalk species, followed by the remaining trias horizons.

Muschelkalk.

In a former paper[1] I have correlated this series and also the black productus shales below with the Werfen beds of the Eastern Alps, and the succeeding divisions

[1] Rec., XIII, p. 99 *et seq.*

with certain other zones found in the Alpine trias. This, however, I find untenable; though in general features and in the main divisions there is no doubt that the trias of the Central Himalayas is closely related to the trias of the Eastern Alps.

Otoceras stage (passage-beds).

The beds with *Otoceras woodwardi* form a true passage-bed from the permian productus shales into the lowest trias. Its exacts homotaxis can now be established, for beds containing a fauna nearly related to the Himalayan one have been found in both Western Asia (Araxes) and in Sicily within the last few years. The fact of the disappearance of the *producti*, and of the general habitus of the *cephalopod* fauna reminding one of triassic horizons, have determined me to class the *Otoceras* zone—a passage stage—with the trias, while it may be probably correlated with the lowest formations of the Bunter; but there is really no sharply-defined boundary, no stratigraphical distinction between any division from the permian productus beds (10) to the uppermost rhætic strata, the entire range of beds in fact belonging to one unbroken system of deposits.

Sequence of trias in Spiti.

I will not here enter into a detailed description of the remaining trias and rhætic beds in Spiti, but shall only give a table showing the main divisions of the succession of strata.

In descending order:—

20. Bituminous, sometimes oolitic limestone of a few feet in thickness, with liassic fossils		Lias.
19. Limestone with many fossils; *Rhynch. austriaca*, *Ter. gregaria*		Rhætic.
18. *Lithodendron* limestone		
17. Limestone with *Megalodon sp.*		
16. Dolomites; great thickness		
15. Limestone and shales with fossils	upper.	Trias.
14. *Daonella* limestone; great thickness		
13. Light grey limestone; *Ptychites gerardi* and other Muschelkalk forms	lower.	
12. *Brachiopod* limestone		
11. *Otoceras* beds (passage-bed)		
10. *Productus* shales		Permian.

This sequence of beds is well seen between Muth and Tilling, west of Khar, between the Spiti river and the Manirang pass, etc. It forms a large part of the Spiti area, and in places shows immense flexures and reversions. In my forthcoming "memoir" I shall give a description of the various triassic sections seen in Spiti.

Points of difference with Stoliczka's correlations.

From the above sketch of the formations in Spiti it appears that Stoliczka's views with regard to them must be modified in the following points:—

(1) The silurian closes with the flesh-coloured quartzite series (4) and not with the "Muth quartzite" (8), which is carboniferous; already correctly surmised by Oldham.

(2) A dark limestone (5) may be either lowest carboniferous or devonian; probably the latter.

(3) The carboniferous is in great force and reaches up into the fossiliferous limestone (9).

(4) The black *productus* shales (10), the Kuling shales of Stoliczka, belong structurally to the group of beds which ends with the rhætic and lias limestones, and they are probably of permian age.

(5) The middle trias (Muschelkalk) does not rest immediately on carboniferous as Stoliczka thought that it did; but at Muth, at Kuling, and other localities in Spiti it rests on beds with lower trias fossils, which again are linked through the *Otoceras* passage-beds with the permian *productus* shales.

Mazár-i-Sharif,
Afghan Turkistán,
11th March 1889.

Report *on the* Cherra Poonjee Coal-Field, *in the* Khasia Hills; *by* TOM. D. LA TOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.* (With a plan.)

The coal of Cherra Poonjee occurs near the top of an isolated ridge, between the station of Cherra and the village of Maomlu, steeply scarped on nearly every side, and rising to about 300 feet above the general level of the plateau on which the station is built. A bed of limestone, about 75 feet thick, resting immediately upon the sandstones composing the plateau, forms the base of the ridge, and upon this rest several beds of sandstone and shale, containing one seam of coal which occurs at from 10 to 15 feet above the limestone. The whole of these beds, including the limestone and the sandstones of the plateau, are nearly horizontal, having a slight inclination to the south or south-west; so that the seam of coal, which, with the beds accompanying it, was formerly of much greater extent, is cut off on every side by the steeply scarped hill-side, and its outcrop, if not concealed by jungle or débris fallen from above, would form a continuous ribbon, following the contour of the hill. It is thus an easy matter, by measuring along this contour line, and ascertaining the thickness of the seam wherever it is exposed, to arrive at an approximate estimate of the total amount of coal contained in the hill.

2. The coal appears to have been first worked in the year 1840, when Colonel Lister was Political Agent for the Khasia Hills, and obtained a perpetual lease of the mines from the Raja of Cherra, to whom the ground belongs. Considerable energy seems to have been shown in opening out the field, as I find from Dr. Oldham's account of it in Vol. I, pt. II of the Memoirs, Geological Survey of India, published in 1858, that during the four years succeeding 1840, about 8,500 tons of coal were sent down by Colonel Lister to Calcutta and other places. But since then the mines have been in the hands of private companies or individuals, and in the 44 years that have elapsed since 1844, the amount of coal extracted has actually been less than that mined in the four years they were under Colonel Lister's management. Probably the want of a market nearer than Calcutta would account for this

for in those days the tea gardens of Sylhet were in their infancy, and there were no steamers running on the rivers of the district. But this has all been changed of late years. So important was the field considered at that time, that Lieutenant Yule, R.E., was commissioned to draw up a scheme for carrying down the coal to the plains. After careful surveys he proposed the construction of self-acting railed inclines; a project which was revived some years ago, and carried nearly to completion by the late Major Willans, R.E., though the bringing down of coal from Cherra was apparently not the main reason for the undertaking, owing perhaps to a mistaken idea that the coal had been nearly exhausted. This project, I firmly believe, only requires the expenditure of a little energy, such as animated the pioneers in the working of the coal-field, to become a complete success. As it is, the remark made by Dr. Oldham in his memoir thirty years ago still remains true,—" And to the present day any coal brought down from these mines is carried on coolies' backs, as at the first."

3. The idea to which I have alluded, that the coal is already nearly exhausted, may be partly due to an error made by Dr. Oldham in estimating the total amount of coal: he took the area of the field to be one third of a square mile, which is not very far from the truth, according to my survey; but in making his calculation he altered this to one third of a mile square, or one ninth of a square mile, thus making the total quantity of coal only 387,000 to 447,000 tons, instead of from 1,200,000 to 1,370,000. Besides this, the manner in which the coal is worked by the Khasias might also give rise to the idea that the supply is nearly exhausted; for as soon as they have driven a gallery some 100 or 120 feet in from the outcrop, they abandon it, partly because it is easier to begin a fresh one than to continue digging at such a distance from the surface that lights become necessary, and partly from superstitious reasons, but on no account because they have come to an end of the seam. Thus, the numerous old workings along the outcrop would lead one to think that a much larger amount of coal has been extracted than is really the case. I measured all the mines, both old and new, that could be entered, as carefully as possible, and found that the amount already extracted is only about 6,500 tons; to which should be added that extracted in Colonel Lister's time, for the mines then being worked were on the eastern face of the hill, towards the station of Cherra, as appears from a woodcut in Dr. Oldham's memoir. This would make the total quantity of coal removed since 1840 only 15,000 tons, the insignificance of which may be imagined when it is considered that a difference of only *1 inch* more or less in the average thickness of the seam over the whole area estimated for, would make a difference in the total amount of coal, one way or the other, of over 21,000 tons. And I need hardly say that it would be simply impossible to estimate the thickness correctly within such narrow limits. Or, to put it in another way, the amount hitherto removed, if we assume the thickness of the seam to be 6 feet, would occupy less than two of the 200 feet squares shown on the plan.

4. The survey of the coal-field that I have lately carried out has been made as carefully as the nature of the ground would permit; the greater part of it is covered with very dense scrub jungle, through which it was extremely difficult to follow the line of outcrop; but the number of times that we came upon coal in places where even the natives did not know that outcrops existed lead me to think that the line

I have drawn is not very far from correct. The outcrop at the point marked X on the plan on the western side of the field, is in a rather anomalous position, and I am inclined to think that a fault running from north to south through this point, with a down-throw of about 40 feet to the east, occurs here. Such a fault is mentioned by Dr. Oldham as occurring on the western side of the field, but his map is too small to show its position. In any case it does not affect the quantity of coal to any great extent. It is probably due to a sinking in of the surface to the east, caused by removal of the underlying limestone in solution by water, as has happened in many other places in the neighbourhood. In some cases, where the limestone beneath has been largely removed, the surface beds have fallen in, forming circular depressions or swallow-holes, which sometimes extend down to the seam. A large one, surrounded with a fringe of mines now being worked, occurs close to the G. T. S. station of Ranzsanobo, and is shown on the plan.

5. It will be seen from the plan that the thickness of the seam is by no means constant, though it rarely seems to be less than 3 feet, while in places it reaches as much as 9 feet. It is therefore difficult to form a reliable estimate of its average thickness over the whole area, and I have preferred to divide this into smaller areas, taking what I considered to be a fair average thickness for each. When the cubic contents of each of these are added together, and assuming that one cubic foot of the coal weighs one maund (of 27 to the ton), which is very nearly its exact weight, the total is found to be 1,184,369 tons, which must be taken as only an approximation, the real amount being rather more or less, according as I have over or underestimated the average thickness of the seam.

6. Owing to the manner in which the coal is distributed, as a nearly horizontal seam cropping out all round the sides of detached hills, and at no great distance, not more than 150 feet or so, vertically below the highest point of the hills, it should be possible to extract nearly the whole of the coal, if the mining is carried on upon correct principles and under efficient supervision. At present the Khasias, as I said before, follow their own devices, opening fresh galleries as soon as they have driven those they are at work upon to a certain distance, and capriciously abandoning many even before they have reached such a depth from the surface as to necessitate the use of lights. They hardly ever make any attempt to work out the coal between adjoining galleries, as this would oblige them to use props for the roof, and the coal forming the sides of these galleries, as well as that in the abandoned workings, must be slowly, but surely, deteriorating in quality, exposed as it is to the air and the excessive dampness of the Cherra climate. The small coal also, which must be produced in the operation of hewing the coal, which would form excellent coke, or could be used on the spot for lime-burning, as there is an inexhaustible supply of limestone immediately below the coal-beds, is either thrown away or burnt and entirely wasted, the coolies only taking the larger blocks, which are easily carried on their backs. A competent practical miner could soon instruct the Khasias how to work the mines in a systematic way, and as they are not unintelligent, his services would not, I imagine, be required for a very long period. At present they are only carrying on the methods shown them when the mines were first opened, and they do not improve merely because they have been taught no better plan of working. As the mines are extended further towards the

centre of the hill, it may become necessary to sink shafts to meet the seam, but none of these need be more than 100 feet deep, and no expensive winding machinery will be necessary to bring the coal to the surface. Nor is any pumping machinery required, as the workings can always be constructed, so as to drain themselves, owing to the slight inclination of the seam to the south, and the position of its outcrop, above the drainage level of the surrounding plateau. Another advantage is, that the outcrop on the eastern side of the field, where the seam is from 4 to 7 feet thick, is within a few hundred yards of the tramway between the Cherra terminus and Maosmai, and the coal could be lowered directly from the pit's mouth into the trucks below, either through a wooden shoot, or by means of a short branch incline: while the remainder of the field is altogether above the level of the tramway, so that loaded trucks could be sent from any point down an incline to reach it.

7. But there is not much use in having so fine a seam of coal, possessing so many advantages, available, unless some better arrangements are made for its carriage to the plains than those which now exist. Perhaps some 30 or 40 maunds are now being taken down per day, where at least as many tons should be carried; and there is little doubt that a large and steady supply would meet with a ready sale in the tea districts of Sylhet, and on the steamer lines of the Surma valley;—not to mention the fact that this is one of the few Indian coals that can be used on board ocean-going steam-ships, and that it would very likely be possible to obtain a contract for supplying some of these vessels in Calcutta, if a steady supply were forthcoming. To carry such an amount of course the completion of the nearly finished tramway would be necessary, and for my part, speaking of course as an amateur on such a question, I cannot see where the great difficulty lies in completing it. I have seen many of such tramways in the west of England, several of much rougher construction than this, and no difficulty occurred in working them. One in particular I would mention, at the Clee Hills in Shropshire, which is used for bringing down "Dhu stone," a basalt much used for pavements and road metal, and about three times as heavy, bulk for bulk, as the Cherra coal, from the top of the hill. It is nearly a mile long, and built on the ordinary gauge of English railways, so that it is much larger than any of those at Cherra. Three or four trucks, full of stone, descend at each journey, pulling up the same number of *empty* ones, the brake power being trusted to to prevent the descending trucks running away. Now at Cherra, I believe, in any experiments that have been made, the descending trucks have been arranged so as to only slightly overbalance the ascending, no reliance being placed on the extremely powerful brakes, one an automatic hydraulic brake, and the other applied by hand, to prevent their exceeding a certain velocity; and naturally, when the descending truck is on a less inclined portion of the tramway than the ascending, the whole arrangement ceases to move. I should like to see, say, two or more trucks full of coal or limestone drawing up empty trucks sent down each incline in turn, and I believe the result would be entirely satisfactory. Want of experience, in such a special form of engineering, probably accounts for the failure, and the remedy is obvious.

8. The length of time that the coal-field will last, will of course depend upon the carrying capacity of the tramway and the amount of labour employed in mining; but, supposing that the tramway can carry down 1,000 tons per month, or 12,000 tons a

year, the coal, allowing 5 per cent. for wastage, should last at least ninety years. The amount derived from the sale of the coal and coke should be all clear profit, as its weight would be used to bring up goods from the plains, the freight on which should suffice to pay for maintenance, supervision, &c., of the mines and tramway.

9. There is one point which was noticed by Dr. Oldham, and which calls for consideration,—namely, the clause in the lease of the mines given by the Raja of Cherra to the Government in 1840, whereby the subjects of the Raja are not to be prevented from working the coal seam on their own account. This clause, if carried out, would effectually prevent any systematic plan of working the mines being successful, as is pointed out very forcibly by Dr. Oldham, to whose remarks on the subject I would draw attention.[1] But, if it is decided to work the mines properly, the present Raja might be induced to agree that any works carried on by his subjects should be placed under the same supervision as the remainder of the mines.

10. The geological age of the Cherra coal is determined by the fact that it rests conformably upon limestones which are known by the fossils (Nummulites and others) they contain to belong to the Eocene or lowest division of the Tertiary period. To this period also belong several of the other small coal-fields of these hills, and the large seams near Makum in Upper Assam are also referred to it. The analyses of the coal given below show that it could be used with advantage either as a steam coal or for the production of gas, while its toughness renders it suitable for stowage on board steamers or locomotives, though from the absence of definite jointing it is somewhat inferior in this respect to good English coal.

Analyses of the Cherra coal.

1. By Mr. James Prinsep—

Volatile matter	37·1
Carbon	62·0
Ash	0·9
	100·0
Water	7·0

2. By Captain James—

Description.	Sp. Gr.	Cubic feet of gas per ton.	Percentage of coke.	Illuminating power of gas in candles.	Sp. Gr. of gas.	Remarks.
Massive, fracture irregular in all directions, streak dark brown, decrepitates slightly, swells and fuses.	1·278	10·200	58·	15·	·424	A capital coal for steamers, being difficult to break, and would stow tolerably well; the coke is good and the gas particularly clear and white.

[1] Mem., G. S. I., Vol. I, Pt. II, p. 197.

Note *on a* Cobaltiferous Matt *from* Nepál. By E. J. JONES, A.R.S.M., *Deputy Superintendent, Geological Survey of India.*

Early in 1878 a specimen of a smelted substance from Nepál was examined by Mr. F. R. Mallet, and found to be a cobaltiferous matt, containing 11 per cent. of cobalt. Nothing was ascertained as to the origin of this undoubtedly artificial product (Manual of Geology of India, III, p. 325), and nothing more was heard of it till February 1888, when the Resident in Nepál forwarded some of what is evidently the same substance for examination. This specimen was obtained from Mr. Duncan Ricketts, who states that he was informed by the natives who supplied him with it, "that there are several smelting mines of the stuff, and that it is only obtained close by the copper mines in Nepál. The name of the locality is Kachipatar Argah, Zillah Sowrobhar, about 80 miles north of Doolha. The price on the spot is R30 to R35 per maund, and they sell it here (Doolha) at from R40 to R50 per maund." Doolha appears to be near Birdpore in Basti. After some correspondence, a further small supply was obtained, which I examined. The substance was in the form of a round flat cake, 6½ inches in diameter and ½ inch thick, of a dark-brown, partly black, colour outside; the upper surface being fairly smooth and flat, while the under surface was covered with irregularities, as though it had been run out on an uneven surface in a liquid or viscous state and allowed to solidify. The fracture is dull grey metallic; and the upper half is filled with air cavities. In the original specimen examined by Mr. Mallet, there were two layers, a light and dark grey, but, though this can be seen in some of the more recent specimens, it is not so in all. It is slightly magnetic.

On analysis the newer specimen proved to consist chiefly of sulphide of iron.

Analysis.

Loss at 100° C.	0·40
Insoluble in acids	0·70
Sulphur	20·41
Cobalt	13·97
Iron	62·82
	98·30

together with traces of copper, antimony, and lime.

On polishing a fractured surface, particles with a bright metallic lustre are seen to be irregularly distributed through the grey mass; and on treating with sulphate of copper, metallic copper was deposited.

The substance, therefore, probably consists in great part of a mixture of FeS and Fe_2S, together with free cobalt and possibly iron, produced by a process of concentration analogous to the concentration smelting of nickel ores for the production of matt; though Mr. Ricketts' statement about the proximity of the copper mines would seem to indicate that it may be a by-product of the copper-smelting. Mr. Mallet states in a note that "cobalt is principally used in the state of oxide for colouring pottery and glass, and 13·97 of the metal is equivalent to 16·69 of oxide. Assuming therefore that the specimen analysed is a fair average sample, the 'cheep' would yield nearly a

fifth of its weight of cobalt oxide. It appears from the mineral resources of the United States for 1886 (the last available)[1] that 14,215 pounds of cobalt oxide were imported in that year, valued at $22,757, which is at the rate of £717 per ton. According to Mr. Ricketts' information, the cheep is sold at Kachipatar, the place of production, at R30 to R35 per maund, and at Doolha at R40 to R50. These prices are equivalent (taking the rupee at 1*s*. 4*d*. and 27·22 maunds as equal to one ton) to £54 to £64 and £73 to £91 a ton. As 5 tons of cheep therefore (containing 1 ton of cobalt oxide) would be worth at the above prices £270, £320, £365 and £455, and the cobalt oxide would be worth, after extracting, about £700 (to £650) (1), there would appear to be a fair margin to allow of the cheep being exported to England and treated there; that is to say if it is obtainable in sufficient quantity. The metallurgical treatment of cobalt ores being rather difficult, it does not seem probable that the natives of Nepál are acquainted with any process by which a fairly pure oxide can be obtained."

No information was received with the specimens as to the mode of occurrence, quantity, or treatment of the original ore.

NOTICE.

The President of the Geological Society of London on the International Geological Congress of 1888.[2]

Dr. W. T. Blanford having already in these Records[3] given reports on the International Geological Congress at Bologna (1881) and at Berlin (1884), at which meetings he then represented the Geological Survey of India officially, he has, in his second year of the Presidentship of the Geological Society, made the subject of the Congress in London the theme of his Address. To geologists in India, and particularly to the Survey, many of whom look upon our old colleague as their master and guide in the study of Indian Geology, the reproduction in a further accessible form of so much of the address must be of interest and great use; and as such, the liberty has been taken of reprinting it in full in our Records.

"To English geologists generally, and especially to the Fellows of the Geological Society of London, the most interesting occurrence of the past year in connexion with our science has been the meeting of the International Geological Congress in this city. The history of that body is so well known that it is unnecessary for me to recapitulate it further than to remind you that the idea of a Congress originated in the United States of America, at the Buffalo Meeting of the American Association for the Advancement of Science, in 1876; and that meetings of the Congress have since been held at Paris in 1878, Bologna in 1881, Berlin in 1885, and London in 1888.

[1] In the volume for 1887, since received, the imports for that year are given at 28,681℔, valued at $42,034, which is at the rate of £657 per ton (£1 = $5).

[2] Address *delivered at the* Anniversary Meeting *of the* Geological Society of London, *on the* 15th of February, 1889; *by* W. T. Blanford, LL.D., F.R.S., President of the Society.

[3] Records, Geological Survey of India, XV, pp. 64-76; XIX, pp. 13-22.

"But although the history of the Congress itself has been related in some detail on more than one occasion, and recently by Prof. Prestwich in his opening address to the London Congress, I have met with no general account in English of the work done by the Congress and its committees. As I have had the advantage of taking part in the last three Congresses, and as I have attended most of the meetings of the International Committee for the unification of nomenclature since 1881, I may perhaps be able to give to the Fellows of this Society a few additional details, and thence to pass to the consideration of the question how far the action of the Congress hitherto has fulfilled the expectations of its founders.

"In order to explain the subject to those who have not followed the history of the Congress closely, it will be necessary to go into some detail, and I must ask the Fellows of the Geological Society to bear in mind that in treating of a body mainly composed of European geologists, I occupy to some extent an alien position. At Bologna and at Berlin I attended the Congress as the official representative of the Geological Survey of India, and it is probable that on several questions English geologists hold views differing materially from mine, whilst if the Reports of the British Sub-Committees on classification and nomenclature, and the Preface by Prof. Hughes, as presented to last year's Congress, faithfully represent the opinions of British geologists, I am obliged to dissent in some respects, as I will endeavour to explain hereafter.

"I must also point out that several of the subjects to which I propose to refer, have been treated with great clearness by Prof. G. K. Gilbert in his able address read at New York in August 1887, to Section E of the American Association. In the majority of Prof. Gilbert's views I heartily agree, and like myself he regards the whole question from an extra-European standpoint.

"There may be some difficulty in ascertaining what were the expectations of the geologists who originally suggested the idea of the Congress, and it may even be questioned whether the anticipations of all who assisted in the conception of that body were similar. The object of the Congress, as expressed in the resolution passed by the meeting of the American Association in 1876, was 'for the purpose of getting together comparative collections, maps, and sections, and for the settling of many obscure points relating to geological classification and nomenclature,' &c.; and this object was further defined and, so far as it is possible to judge, correctly defined at the Paris Meeting, where two International Committees were appointed, the one to deal with the unification of geological nomenclature, the other to propose a general system of coloration and signs for geological maps. A third committee, composed entirely of French members, was formed to consider the rules of palæontological and mineralogical nomenclature.

"Of the subjects referred to the third committee, one, and that the only one upon which a report was presented and action was taken, was clearly beyond the scope of a Geological Congress. Palæontology, so far as the nomenclature is concerned, is purely a branch of biology, and palæontologists must adhere to the rules of nomenclature already established in zoology and botany.

"Unfortunately zoological rules have not the same general acceptance as botanical; some zoologists are men with but little scientific training and imperfectly informed, and a few refuse to submit to any rules but those of their own caprice; consequently, as palæontology depends more upon zoological than on botanical nomenclature, there is much excuse for the offences against the rules of nomenclature in which it must be admitted that a few palæontologists indulge. This eccentricity in nomenclature on the part of a few palæontologists doubtless led to the nomination of a committee and to the proposal of a set of rules which, after discussion and amendment, were adopted by the Bologna Congress. These rules differ in no important respect from the Stricklandian Code of the British Association, adopted by a large majority of English and by many foreign zoologists. Although, as has already been said, the subject is not one on which a Congress of geologists is entitled to speak with authority, it is but right to say that the discussion at Bologna was left entirely in the hands of biologists, and was closer, more to the point, and more free from intervention by unqualified speakers, than any other discussions that took place at that meeting; in fact, coming at the conclusion of the week's proceedings, the sittings were only attended by those who were interested in the question. The conclusions are therefore well worthy of the attention of palæontologists.

Amongst the most important are the exclusive acceptance of binomial terms and of the rules of Latin orthography, and the rejection of pre-Linnæan names. The rule that in future no palæontological specific names should be recognized as valid unless the species is figured as well as described, is also of great importance. One minor point, the recognition, under the name of 'mutations,' of geological varieties, or forms, in strata of different age, corresponding to the geographical varieties or races inhabiting different areas on the earth's surface, was a useful addition to palæontological terms.

"The two more legitimate undertakings of the Bologna Congress have had a longer and more checkered history, and the story of the two has become much interwoven. Originally, as most geologists will remember, the two international committees, that for geological maps and that for nomenclature, were composed of a number of geologists, fourteen in the first case, fifteen in the second, each of whom represented his own country, and each of whom was expected to form, in that country, a national committee who should report to the general or international one. In the majority of cases such national committees were formed; but, as might be expected, several sent in no reports, whilst the recommendations of others were received too late to be noticed in the General Report drawn up by the Secretary of each international committee and laid before the Congress.

"The result was, that the General Report on the unification of map-coloration and signs, drawn up by Prof. Renevier, the Secretary of the International Committee, was founded on reports from Russia, Switzerland, France, Italy, Spain and Portugal (combined), and Belgium. No reports had at that time been received from the committees formed in Germany, Austria, Great Britain, Scandinavia, or the United States. A Report from the English Committee was received at the Bologna Congress, but was never before the members in a printed form. In short, of the fourteen countries represented on the international committee, the views of less than one-half were in the hands of the Secretary when he drew up his General Report.

"The question of map-coloration was, however, not only important but urgent. It is easy to look back now and to see that the Bologna Congress would have acted with greater wisdom had it postponed several of the questions on which a decision was taken; but it might fairly have been urged, on the other hand, that the crucial experiment of deciding scientific questions by the vote of a Congress was worth trying. Failure might have been foreseen; but as there were many believers in the wisdom of majorities, it was well that they should have an opportunity of being undeceived. At all events a proposal was made by Prof. Renevier to establish a colour-scale for geological maps, and it is possible that, had his proposals been adopted as they stood, the scale would have had a better chance of being generally accepted than has that employed in the map of Europe. As Professor Renevier's original scheme has been to a great extent forgotten, it may be as well to recall it.

"The whole of the sedimentary rocks were classed in four 'series' (this was, of course, before a different signification had been allotted to the term), archæic, palæozoic, mesozoic, and cænozoic; and each of the three latter was divided into three parts, to each of which a distinct tint was assigned. It was proposed that recent formations should be left white, and that the other sedimentary strata should be coloured as in the following list:—

CÆNOZOIC.	Pliocene (including Pleistocene).	Pale sepia-yellow tinted orange.
	Miocene.	Brownish yellow (Jaune chamois).
	Eocene.	Gamboge-yellow.
MESOZOIC.	Cretaceous.	Green.
	Jurassic.	Blue.
	Trias.	Brick-red.
PALÆOZOIC.	Permo-carboniferous.	Dark Grey.
	Devonian.	Brown.
	Silurian (including Cambrian).	Violet.
ARCHÆIC.		Pink.

"With regard to igneous rocks no recommendations were made, the subject being regarded as not sufficiently studied. To one of the observations, however, which appears to me very important, I shall revert presently.

"The Bologna Congress, it will be recollected, only decided upon the colours for Pre-Cambrian and Mesozoic rocks, and in doing so accepted Prof. Renevier's proposals, with the exception that, on his own recommendation, violet was adopted for Trias instead of brick-red,

as had been proposed in the printed report. Yellow tints were accepted for Tertiary systems, the higher beds to be represented by paler shades. The selection of hues for Palæozoic rocks and the whole question of the coloration to be adopted for igneous formations, were referred to a committee appointed to arrange for the publication of a geological map of Europe.

"There can be little doubt that the adoption, almost without discussion, of a different colour from that originally recommended for the Trias, was one of the greatest mistakes made by the Congress. The question should have been postponed. But, in point of fact, the question of the colours to be adopted for maps is one of which very few geologists have any wide experience, and it is consequently one which a congress of geologists is ill-qualified to discuss.

"Before passing away from Prof. Renevier's Report, it is as well to call attention to the circumstance that some very useful proposals were accepted unanimously by the Congress. These were :—(1) that different shades of a colour (or, as some express it, different tones of a hue) should be adopted for subdivisions of a system, the darkest shade being employed for the oldest subdivision; (2) that the lettering or literal notation for sedimentary rocks in general should be founded on the Latin alphabet, and that for igneous rocks on the Greek; (3) that each sedimentary system should be represented by a corresponding capital letter (*e.g.*, Jurassic by J), principal subdivisions of each system by the addition of a small initial letter (Portlandian by Jp), and the minor subdivisions by figures (Jp^1, Jp^2, &c.), the most ancient of the latter being represented by the lowest figure.

"One other contribution to the question of map-coloration and signs was furnished by the essays sent in to the Congress to compete for the prize of 5000 francs (£200) offered by the King of Italy for the best memoir on these subjects. Although not one of the papers offered was deemed worthy of the full prize, three received awards and were published in the General Report of the Congress. All of these—and especially the first, by M. Heim, of Zurich—contain useful suggestions.

"The principal result of the whole discussion in the various Committees and in the Congress was, however, a resolution to publish, under the auspices of the Congress, a general geological map of Europe, on a scale of 1/1,500,000 (between 23 and 24 miles to the inch). It was arranged that the map should be prepared in Berlin under the direction of Prof. Beyrich and Mr. Hauchecorne, and the superintendence was entrusted to a Committee composed, in addition to the Directors and the Secretary (Prof. Renevier), of representatives of France, Italy, Russia, Austria, and Great Britain. This Committee has gradually become a kind of general referee, to which all difficulties and contested points have been left for solution.

"The second International Committee already noticed—that for unification of geological nomenclature—should have been first mentioned, if the various subjects presented for consideration to the Bologna Congress were arranged in the order of their relative importance. I have, however, left it for the last, because it appears to me to be the subject in which the smallest result was obtained. The National Committees certainly began at the beginning, but for the most part they unfortunately ended their labours before arriving at any conclusions of scientific importance. It may fairly be doubted whether the American founders of the Congress contemplated laying down rules for the abstract terms to be applied to subdivisions of strata or of geological time. But congresses, unlike men, do change their minds when they cross the ocean, and the geological ideas of Paris were naturally very different from those of Buffalo. It was only natural that the first two Congresses being held amongst people of the Latin races, terms should be treated with the precision essential in the language employed at the Congress. Another consideration to be borne in mind is, that a very large proportion of the leading geologists are engaged in teaching students, and are consequently inclined to attach great—possibly, in some cases, too great—importance to an exact definition of the terms to be used.

"It is scarcely necessary to recall to your recollection the geological terms agreed upon by the Bologna Congress—how the words *rock* and *formation* were defined; how it was resolved to divide the whole geological sequence of strata into *groups*, *systems*, *series*, *stages*, and '*assises*,' and to employ as terms of duration equivalent to the first four the words *era*, *period*, *epoch*, and *age*. Unfortunately these terms, when adopted, were, by the nature of the case, by no means rigorously defined, as it was impossible to say what was the relation in magnitude between, for instance, an epoch and a period; and although no difficulty was found in the division of all sedimentary rocks into great groups, and of geological time into great eras, the

case was different when an attempt was made to divide the Palæozoic, Mesozoic, and Cænozoic groups or eras into systems or periods and series. This took place at a subsequent stage.

"As in Paris, so in Bologna, the consideration of the further steps to be taken towards the establishment of uniformity in geological nomenclature was entrusted to a Committee composed, on this occasion, of 17 members, each representing a separate country. Meetings of this Committee, and of that for the geological map of Europe, were held together in September 1882 at Foix in the Pyrenees, and in August 1883 at Zurich in Switzerland. Both meetings, considering that the members of the Committees came for the most part from distant parts of Europe, were well attended. Of the 17 members of the Nomenclature Committee, 8 attended at Foix and 9 at Zurich; whilst of 8 members of the Committee for the preparation of a geological map of Europe, 5 were present on each occasion and took part in the discussions on nomenclature. These were mainly devoted to a classification of sedimentary and igneous rocks to be recommended to the Geological Congress of Berlin for adoption in the geological map of Europe. Questions *relating* to the coloration of the map were discussed by the Map Committee sitting by itself. Thus the whole question of unification, both of maps and of nomenclature proper, between the Bologna Congress of 1881 and the Berlin Congress of 1885 (and I think more real progress was made during this period than either before or after), was mainly limited to a thoroughly practical undertaking—the general classification of rocks, and the general system of coloration for adoption in the geological map of Europe. But although there were many advantages attending the practical form that the question of unification had taken, there was a serious disadvantage in the limitation of the discussion to Europe; and, in fact, this change involved a complete departure, unless I am much mistaken, from the intentions of the geologists by whom the original scheme of a congress was proposed.

"A scheme of classification in groups, systems, and series was drawn up by a committee of German geologists and submitted to the International Committee for approval. It may be useful to quote side by side the original list and that which was finally accepted for the map:—

1. Gneiss and Protogine.	Gneiss.
2. Crystalline schists.	Crystalline schists.
3. Phyllites.	Azoic schists.
4. Cambrian.	Cambrian.
5. Lower Silurian.	Lower Silurian.
6. Upper Silurian.	Upper Silurian.
7. Lower Devonian.	Lower Devonian.
8. Middle Devonian.	Middle Devonian.
9. Upper Devonian.	Upper Devonian.
10. Lower Carboniferous.	Lower Carboniferous.
11. Upper Carboniferous.	Upper Carboniferous.
12. Lower Permian.	
13. Upper Permian.	Permian.
14. Lower Trias.	Lower Trias.
15. Middle Trias.	Middle Trias.
16. Upper Trias.	Upper Trias.
16′. Rhetian.	
17. Lower Jurassic.	Lower Jurassic.
18. Middle Jurassic.	Middle Jurassic.
19. Upper Jurassic.	Upper Jurassic.
20. Lower Cretaceous.	Lower Cretaceous.
20′. Gault.	Upper Cretaceous.
21. Upper Cretaceous.	
22. Eocene.	Eocene.
22′. Flysch.	Oligocene.
23. Oligocene.	Miocene.
24. Miocene.	Pliocene.
25. Pliocene.	
26. Diluvium.	Quaternary.[1]
27. Alluvium.	Modern.

[1] From a note by Prof. Renevier, I learn that this term will be replaced in the published map by Pleistocene.

"On the classification of both sedimentary and plutonic formations many reports were received from different National Committees. Several of these reports contained replies to particular questions that had been circulated as to the classification of certain subdivisions, such as Gault and Rhætic and the method of dealing with strata of indefinite or transitional age, such as the Flysch.

"One very important proposition was brought before both meetings by Prof. Neumayr—that of the publication of a '*Nomenclator Palæontologicus*,' to contain a complete list, with full references to description, locality, and stratigraphical position, of all fossil species of animals and plants described up to the date of publication. The plan was approved by the Committee and received most favourably by the Congress of Berlin. Unfortunately, financial difficulties have hitherto prevented the scheme from being carried out. This is greatly to be regretted; it is difficult to name an undertaking that would prove a greater benefit to palæontology, or one that would afford greater aid towards carrying out a uniform nomenclature.

"The meeting of the Berlin Congress, which was originally to have been held in 1884, was postponed for a year, because it was thought by the Committee of Organization that the existence of cholera in Southern Europe in the first year might seriously interfere with the attendance of geologists. The Congress met at the end of September 1885, and was well attended, 166 German members and 86 of other nationalities being present. The number of inscribed members absent or present was 456.

"It was evident from the very beginning that there was a marked contrast between the Berlin meeting and that of Bologna. How far this was due to a change of scene, and to the fact that the bulk of the assembly belonged in one case to the Latin and in the other to the Teutonic race, it is difficult to say. These cannot have been the sole causes of the differences, for most of the principal actors were unchanged, and the questions of nomenclature brought before the meeting were susceptible of treatment precisely similar to that employed at the Congress of Bologna. There can, however, be no doubt that a strong reaction had set in against the attempt to decide scientific questions by the vote of a majority; and in one instance, at least, on which opinions were greatly divided, the question as to whether the Permian should be regarded as a distinct system or united to the Carboniferous, the assembly deliberately abstained from voting. This question had already been discussed in the Nomenclature Committee at Zurich, and the numbers who voted on each side were equal.

"It may here be pointed out that there is a great difference between a vote in a body consisting almost entirely of geologists familiar with the subject and of varying nationalities, as are those composing the Committee of Nomenclature, and a vote in a body of which the large majority belongs to one nationality and is composed to a great extent of those who have not paid particular attention to the details under discussion.

"As a result of the meetings in Berlin, the proposals of the Map Committee for the classification of both sedimentary and igneous rocks were accepted with a few modifications. Two questions, however, were especially left over to the next Congress, which was appointed to be held in London last year. These questions were, the arrangement to be adopted for the Lower Palæozoic system or systems beneath the Devonian, and the classification of the Tertiary and (if admitted) Quaternary groups as a whole.

"A considerable proportion of the time devoted to the work of the Congress at Berlin was occupied by the reading of papers on various geological subjects, several of them not relating to the questions before the Congress. Similar papers were sent to Bologna, but were not read, though they were inserted in the General Report.

"The reports from the British Sub-Committees on geological classification and nomenclature were presented at Berlin as a whole (some had been previously distributed), but without the preface subsequently added in the edition of 1888. These reports differed materially from any that had previously been presented. They were far more detailed, and contained a history of each statigraphical subdivision, and much information concerning the distribution and relations to each other of the various series, stages, and sub-stages, so as to afford an epitome, in detail, of the stratigraphy of the sedimentary rocks occurring in Great Britain and Ireland. To the consideration of these reports I shall return in the sequel.

"The Committees for nomenclature and for the map of Europe were reappointed, with but trifling alterations, at Berlin; but the meetings between 1885 and 1888 were comparatively un-

important. Five members only of the Nomenclature Committee, out of the full number (20), met at Geneva in 1886, and eight at Manchester in 1887. Some of the conclusions arrived at by the first meeting, with regard to the modification of the Bologna decisions, met with disapproval at the second—a circumstance mainly due to the difficulty of adopting the same terms in all languages.

"Finally, the fourth Congress was held last year in this city, and brought together a larger body of geologists than any previous meeting. The whole number of members was 830; of these 407 were present, 256 being from the British Isles and 151 from other countries. It must, however, be remembered that for the first time ladies were admitted. The number of well-known geologists was large; as an instance, it may be mentioned that 9 of the Society's foreign members and 13 foreign correspondents attended the meeting.

"A fresh change took place in the method of procedure. At Bologna the reports drawn up by the Secretaries of the different Committees were discussed paragraph by paragraph, and accepted, modified, or rejected after a regular discussion. At Berlin certain parts of the reports were accepted with little or no modification, others postponed. In London the reports were almost ignored, and only three subjects were discussed; two of these were the questions already mentioned, relating to the classification of Lower Palæozoic and of Post-Secondary rocks, and the third was a fresh subject of discussion—the origin and history of the crystalline schists—brought forward by the Organizing Committee and treated in a novel manner, by obtaining and printing beforehand dissertations from several specialists. On none of the subjects named was there any attempt to arrive at a decision: there was simply a discussion. It may be added that, whereas in one of the stratigraphical questions—the Cambrian and Silurian—there was some approach to a general agreement about the principal facts, and in the other a majority of the speakers were in favour of a particular view, the subject of the crystalline schists was left as chaotic as ever, or as, according to some of the disputants, were the conditions of the geological era when the schists themselves were formed. So far the discussion has scarcely tended towards unification of either nomenclature or views; the Neoneptunists still stand widely apart from the Neoplutonists; nor does there appear to be any prospect of agreement between those who pin their faith on gradual chemical or hydrothermic action and those who believe in violent movements of the earth's crust, or between those who contend that the 'Urgneiss' could only have been deposited in the Archæan era and in the depths of the primæval ocean, and those who urge that gneiss absolutely undistinguishable from its pre-Cambrian type has been formed in all geological epochs, and may be forming at the present day under favourable circumstances of heat and pressure.

"The discussion on Tertiary classification, too, was almost confined to one point—the distinction of the Quaternary as an era apart from the Tertiary. The important question as to whether some better classification could not be adopted than that into Eocene, Oligocene, Miocene, and Pliocene, the limits of the different systems, and the desirability of subdivision, at all events in the case of the Eocene, were scarcely mentioned.

"Besides the papers on crystalline schists and the second edition, with the preface, of the British Sub-Committee's reports on classification and nomenclature, there was presented to the London Congress a series of reports by American Sub-Committees on the classification of the sedimentary formations of North America. The importance of this work is due primarily to the fact that it does not refer to the portion of the world that has of necessity been accepted as the standard of comparison for the geological scale; and, secondly, to the circumstance that much of the information has been accumulated very recently, and has not found its way into text-books. A summary of the conclusions, drawn up by Dr. Persifor Frazer and translated by Prof. Dewalque, was circulated separately. It is to be regretted that a similar *résumé* of the reports of the British Sub-Committees was not prepared.

"The history of the Congress, it will thus be seen, up to the present time, is the history of an undertaking begun with great, if somewhat misdirected, zeal and energy, and gradually descending in its aims, till, from attempting to establish an universal geological language, and to regulate the coloration, signs, and scale of geological maps in general, it has contented itself with supervising the issue of a map of Europe in which both classification and colour are admittedly tentative; whilst, instead of deciding points of primary importance by votes, it discusses questions, sometimes of secondary importance, without attempting to lay down any law. In passing from

Bologna to Berlin, and from Berlin to London, there has certainly been a tendency on the part of the Congress to abdicate its early pretensions, to collect information, and to cease from issuing edicts. It now remains to be seen what will be the effects of the meeting of 1891 in Philadelphia; whether the Congress will rise again, Antæus-like, in its pristine vigour, from contact with its native soil; or whether it will resolve itself into the intercalation of a little mild academic discussion between much more largely developed schemes of social amusement—a fashion not unknown in other scientific meetings, especially when ladies are admitted.

"In considering how far the institution of a triennial Congress has hitherto fulfilled the expectations of its founders, it becomes necessary to discuss the apparent results hitherto obtained. These are:—

1. The terms adopted at Bologna;
2. The subdivisions and colouring adopted on the geological map of Europe;
3. The various reports from different national and international Committees, and all other documents published in connexion with the Congress.
4. The exhibition of maps and specimens.

On each of these a few words may be added.

"1. The various terms for strata and time adopted at Bologna have been accepted to a considerable extent abroad, but have as yet found but small favour with English geologists. Even in the reports of the British Sub-Committees on classification and nomenclature there is a complete disregard of all restrictions upon the use of terms.

"It is quite true that the number of kinds of subdivisions made in both stratigraphy and time by the Bologna Congress was rather greater than was necessary, and that the restriction of the two words *group* and *series* to particular subdivisions in the scale renders it very difficult to write upon stratigraphy in English, owing to the poverty of the language in geological terms and to the fact that these two words have been used for every kind of subdivision indiscriminately. The use of *group* for so large a division as Palæozoic and Mesozoic is quite opposed to our habit, as the word has hitherto been more frequently used in the sense of the French *étage* than for any larger division. The proposal repeatedly made by the French and other Committees to transpose the words group and series, and to apply the latter to great divisions like Palæozoic, and the former to divisions of the third order, would be an improvement; but it would be far preferable to diminish the number of subdivisions, and to eliminate both words, group and series, from the restricted list—to revert, in fact, to the original proposal of the English Committee in this respect. Professor Hughes calls attention to a suggestion of Professor Sedgwick's, to use *class* for the largest divisions. I had made the same suggestion myself, in ignorance of Professor Sedgwick's employment of the word, when writing on the subject for the International Committee meeting in Geneva; and I think if English geologists would agree to employ the term *class*, or, as Professor Cope has suggested, *realm*, as the English equivalent of *group*, and to omit *series* and *assise* altogether, as unnecessary, we should have three words left—class or realm, system, and stage—two of which are additions to our very poor list of English terms. I cannot agree with Professor Hughes in objecting to the word *stage* because it is not exactly the equivalent of *étage*; it appears to me a great advantage to have an English word to fit precisely where a term is peculiarly wanted. I feel sure that if English geologists will condescend to try the term they will find it extremely useful. If intermediate or inferior subdivisional names are needed, the terms sub-class, sub-system, and sub-stage might be employed.

"The distinction drawn at Bologna between stratification- and time- words is one of very great importance, and I believe English writers would do wisely and would aid in the progress of the science by adopting the reformed nomenclature. Until there are clear ideas on the subject, and until the distinction of the two categories is rightly appreciated, there is but little hope of any sound classification.

"There is, however, one of the time-words adopted at Bologna that must in English be left for unrestricted use, for the simple reason that we cannot replace it. This is *age*. It is impossible to avoid writing of strata and fossils as of Palæozoic age, of Jurassic age, &c.; and although this might be done without ceasing to use the term as the time equivalent of *stage* it would be better to replace the word by another, or, if the number of subdivisional terms is

diminished, to omit *age* altogether. I would suggest to British geologists for consideration some such scheme as the following:—

Stratification.	*Time.*	*Example.*
Class.	Era.	Palæozoic.
System.	Period.	Jurassic.
Stage.	Epoch.	Oxford Clay (Oxfordian).

If this or some corresponding plan were adopted, there would be no necessity for the adoption of the word *terrane* proposed by Professor Gilbert to be used for a stratigraphical subdivision of any magnitude, though the language would gain by the employment of such a term.

"It must not be forgotten that if, as already noticed, the Bologna Congress failed to define the subdivisions that it sanctioned, the failure depended very much on the inherent impossibility of the task. There is absolutely no scale by which periods or epochs can be measured; all that can be done is to enumerate certain divisions of geological time as represented by particular strata and enact that such subdivisions shall rank as periods or epochs. As the stratigraphical divisions are utterly dissimilar in different countries, the determination for one region will afford but little aid in another. All that can be done, in short, is, as has been admirably pointed out by Professor Gilbert, to adopt an admittedly arbitrary and empirical scale of systems for the sedimentary rocks of Western Europe, as being the best known, and to employ this scale for comparison in other countries.

"The classification of the geological sequence has, in fact, been founded on no recognised system, but has grown up gradually. Just as in a newly-discovered country, or in a barbarous continent in process of annexation by more civilised peoples, a colony has been founded here and there, until by irregular growth, depending for its progress on various circumstances, the borders of the different territories have come into contact and require to be defined. If good natural barriers, such as a mountain-range or a broad river, intervene, these have generally been taken as frontiers; but if not, frequently after much dispute, some less defined line has been adopted. Substitute for colonies strata and for the physical boundaries of rivers and mountains the equally well marked limits corresponding to petrological change, often accompanied by unconformity, and the history of the repartition of the stratigraphical sequence into systems and stages corresponds to the subdivision of geographical areas into states. The story is a story of haphazard, in which scientific induction has played a subordinate part, and the idea of rendering the divisions equal has probably never occurred to any one.

"There is, however, this difference between countries and strata. The mapping out of the former covers the whole area, whilst the latter in any and every country can only represent a certain portion, probably a very small portion, of geological time. The gaps that are unrepresented are an unknown quantity, but are undoubtedly in any given area in excess of that portion of the scale that is represented by strata. Therefore, even if the thickness of strata in any subdivision were directly proportional to the duration of time occupied in the formation of that subdivision—in other words, if the thickness of a system varied directly with the duration of the corresponding period, which it most certainly does not—the duration of the corresponding division on the time-scale would still be unknown, as the time corresponding to the breaks in the sequence is undeterminable.

"2. Under these circumstances, and seeing that anything like an equalized scale is hopeless at present, there is a fair reason for accepting, as has been done in the map of Europe, those periods that are best known. In the Mesozoic era, for instance, in which the relations of the periods are simpler than in the Cænozoic or Palæozoic, there can be very little question that a division of both Cretaceous and Jurassic into two would produce periods much more nearly equal to the Trias in palæontological importance (the only approach to a time-test that we possess) than are the great Cretaceous and Jurassic periods as at present usually adopted. This subdivision of the Mesozoic era into five periods—Cretaceous, Infra-cretaceous, Oolitic, Liassic, and Triassic—has been adopted by several geologists, amongst others by Renevier and by De Lapparent in his 'Traité de Géologie.' It would, however, have required a much more general agreement than exists amongst European geologists to have justified so marked an innovation in the map of Europe. The same remark applies to the acceptance of the Permian as a distinct subdivision, although it is not only inferior in importance to the Trias, but is palæontologically an integral part of the Carboniferous. To reduce such periods as Cretaceous, Jurassic,

Silurian, and Cambrian into a form in which they would represent, even approximately, divisions of the same duration as Pleistocene, Pliocene, and Permian, would involve a complete rearrangement of the whole geological succession. Before an attempt is made at such a rearrangement, it is desirable that a larger area than Western Europe should be selected for the field of experiment.

"When, however, we pass from the systems of the map to their subdivisions, it is difficult to avoid feeling some degree of doubt as to whether a more equable arrangement might not have been adopted, even for European rocks. The Trias is divided into three series, the far more important Cretaceous system into only two, and the Eocene and Cambrian are undivided. It is impossible to avoid regretting that the relative local importance of particular subdivisions has led to the raising of a comparatively unimportant stage like the Muschelkalk to a rank equal to that of Neocomian and Gault combined, or to that of the Lias, together with the Rhætic in many localities, or to that of the whole Cambrian. The fact, of course, is that in this case deference has been paid to a time-honoured classification peculiar to part of Germany and a small area in France. This is an illustration of the evil produced by merely local classifications and by the misleading name under which the Triassic system is known, a name derived from the local subdivision of the system into three well-marked stages, two of which are, in the main, subaërial, fluviatile, or lacustrine, and the third alone marine. The latter, moreover, contained a peculiar local fauna which probably inhabited an inland sea, and differed materially from the true marine Triassic fauna which has now been traced from the Alps and Spitzbergen to Chili and New Zealand. In short, the so-called typical Trias is altogether an exceptional and abnormal system, and useless for purposes of comparison.

"The coloration of the sedimentary rocks in the map of Europe has the very common defect that the colours are in large measure too dark and too opaque; but it is understood that this will be altered to some extent. The system of colours does not give satisfaction in America, nor, so far as is known, elsewhere. It is to be regretted that violet was not kept for Silurian, as proposed by several of the National Committees, and brick-red for Trias, as advocated by almost all; and no doubt the change in this respect has done something to render the system adopted unsatisfactory. Violet between grey (Carboniferous) and blue (Jurassic) is open to the objection that the paler shades are not sufficiently easy to distinguish, whilst brick-red (impure orange) is distinct in all shades.

"It may, indeed, be doubted whether any scheme of coloration could be devised that is free from objection. Much has been said of the advantage of a system based upon the solar spectrum, and, indeed, in the plan adopted there are some lingering traces of a spectral system,—blue, green, and yellow succeeding each other in the Upper Mesozoic and Cænozoic groups. Professor Gilbert has suggested a very ingenious and apparently simple plan of dividing the spectrum into hues defined by their wave-lengths, or, which comes to the same, by their position on the Kirchhoff scale. He is of opinion that from fifteen to twenty sufficiently distinct hues can be thus selected, and these, with the purples which are not contained in the spectrum, would suffice for the different periods. He would then allot brown to igneous rocks.

"This plan has, I believe, one fatal objection. If the adjacent spectral hues are in contact on the map, even though the full tones or shades be distinct, the paler tones will not be so. The only remedy would be to alternate colours from different parts of the spectrum, and then the orderliness of the plan, its principal recommendation, would disappear.

"The fact is that the distinctness of colours adjacent to each other is an essential requirement of any efficient system, though but few of those who have treated of map-coloration in connexion with the Congress have referred to this important point. It must be remembered that all hues in contact should remain sufficiently distinct after a certain amount of fading from exposure, and that all should be easily distinguished by artificial light.

"The classification and coloration of the igneous rocks on the map of Europe is very unsatisfactory, and I shall probably have the hearty concurrence of English geologists in general in condemning the system proposed as impracticable. In the first place, as was pointed out by Professor Renevier some years ago, it is illogical to arrange the sedimentary rocks entirely by their geological date, irrespective of petrological character, and the igneous rocks entirely by petrological characters irrespective of their date of origin. No doubt, in the map of Europe, a petrological distinction is made which is supposed to be connected with

geological age, when diabase and melaphyre are distinguished from basalts, and porphyry from trachyte and its allies; but the supposed connexion between geological antiquity and mineral characters in the case of these rocks is held by the best English petrologists, and on sound evidence, to be erroneous. It is difficult to see why the igneous rocks of which the period is known cannot be represented by the colour of the period to which they belong, but deep and opaque, the petrological character, if it is considered essential, being represented by the monogram; whilst some simple convention might be used for outbursts of unknown period. Or all igneous rocks might be represented by one conspicuous colour, the monogram serving to distinguish the kind of rock. It is difficult to understand why in a map in which no colour-distinction is drawn between limestone and sandstone, chalk and slate, rock-salt and coal, clay and iron-ore, quartzite and gneiss, except that due to geological age, it is essential to distinguish by colour between granite and porphyry, melaphyre and basalts, peridotite and serpentine, although several of these are so inextricably mixed in places that their outcrops could not be disentangled on a map with a scale 100 times larger than that of the map of Europe. It is reasonable to suppose that the assignment of one colour to the lavas of active or extinct volcanoes, another to the ashes and scoriæ, and a third to 'stratified tuffs,' was proposed by geologists who had not much personal experience of volcanoes of either kind. Really the proposal to map the three apart on a scale of 24 miles to the inch sounds like a joke.

"But even accepting the fact that what has been done hitherto must be done in the future, and that the geologists of Western Europe insist on colouring the igneous rocks on a system radically distinct from that employed for sedimentary formations, it is still difficult to understand the advantages of so many subdivisions as have been adopted in the map of Europe, or to understand how it will be possible to colour the numerous outcrops of igneous rocks that are intermediate between two of the ill-defined groups established, or composed of two kinds belonging each to a separate group. Surely, if petrological characters must be the guide in coloration, some simple division, as into basic and acid rocks, would suffice. There would be difficulty even in this, as when trachytic lavas are interstratified with basaltic, or when a rock occurs containing a percentage of silica on the artificial limit between acid and basic rocks; but all difficulties of this kind increase in geometrical ratio with the numbers of groups into which an attempt is made to classify the various rocks.

"Whilst thus criticising some of the details of the map, it would be unfair not to recognise the fact that the Directors have worked under considerable difficulties, having, in fact, been obliged to act very largely on their own responsibility. In all probability no map of Europe would have been produced had not Professor Beyrich and Mr. Hauchecorne undertaken the direction of the work, and all geologists owe a debt of gratitude to those gentlemen. Although it is not likely that this map will determine the questions of coloration and nomenclature, it will doubtless contribute largely to their being settled.

"3. It is probable that the published accounts of the different meetings of the Congress form the most important contribution made by it to Geological Science. The reports from the various National Committees are naturally very unequal in importance, but many of them are excellent, and all of them suggestive.

"In this connexion it will be, I hope, not impertinent if I call attention to the British Sub-Committees' reports. In the preface these reports are held up as a model on which those of other countries should be framed, and it is claimed that 'the greatest advance in the work proposed to be done has, so far, been made in practical England.' A claim of this kind invites criticism, and as the writer is the President of the National Committee, and therefore the representative of English geology, his views are doubtless those of many British geologists. As already noticed, these reports contain an epitome of the detailed stratigraphy of the British Isles, arranged in convenient divisions, the report on each division being written by one or two authors. The history of the various names employed for the different subdivisions in which the strata were classed is given, and the views of the principal observers as to the correlation and classification of the beds in various parts of the country are recorded. There is naturally some inequality; slight differences are, however, to be expected, and taking the work as a whole, there appears to be every reason to believe that the authors have carried out very thoroughly that which they undertook, *viz.*, to give the history, synonymy, and detailed classification of British sedimentary rocks.

"But the question which has occurred to me, and. I think, probably to some of the foreign geologists who have had occasion to consult the 178 pages of details, is this:—In what way does all this work contribute to the Unification of Geological Nomenclature? It is easy to see that the reports under consideration will facilitate the work of those who have to fit the geology of the British Isles to the map of Europe, though even for this purpose some knowledge of the correlation between British and continental strata is necessary. Undoubtedly, too, the information given in these reports will be most useful to compilers of general works on Geology, whilst to all British geologists it will be of advantage to have within reasonable compass so general an account of the British stratified rocks. But unless I am much mistaken, the object supposed to be in view is the establishment of a general classification for the strata of the world, or at all events of Europe, and for this the careful and elaborate details upon which so much labour has been expended by the reporters appear superfluous. As the British strata have been very largely taken as types, especially in the Cretaceous, Jurassic, Silurian, and Cambrian systems, the history of the names is important; but a general table of the beds from top to bottom, arranged according to the latest information available, would have been sufficient for purposes of comparison with the strata of other countries. If comparison with the systems and stages of distant countries was contemplated, far more complete information as to palæontology should have been given. In short, I venture, with some diffidence, to suggest that the work may produce upon those who, like myself, approach the question from a foreign point of view, the impression that there is too much of data that are of little or no use except to local geologists, and too little of the information that would be useful for comparison with the geology of other countries.

"It may be assumed that the principles upon which the work has been compiled are those stated in Professor Hughes' preface. In this he urges the adoption of a natural, as opposed to an artificial system, and points out that the characters of greatest value in the classification of the sedimentary rocks are obviously those which indicate changes of condition affecting sedimentation and life. He then proceeds to explain what he means by an artificial system; and here I would venture to suggest that a different view may be taken of the matter.

"If Professor Hughes had confined himself to urging that in classifying the rocks of any limited region, or even of a country the size of the British Isles, the breaks in stratigraphy, whether petrological or palæontological, must first receive attention, and that such breaks must be accepted as limits of the subdivisions in which the strata are arranged,—if, in short, it were urged that a local classification must depend upon different considerations from those deemed of primary importance in a general classification, his views would necessarily deserve acceptance, since he would only recapitulate the facts upon which all local classifications have been based. But, if I understand him rightly, this is not the position he takes. He contends that palæontological classification, and especially a classification by marine or "pelagic" types of life, is artificial, and that the only natural classification is founded upon local breaks in sedimentation or in life. I am unable to agree with any of the above contentions, and I must say that I shall be very much surprised if in these points Professor Hughes represents the views of British geologists in general. Indeed, in some of the reports that follow his preface, for instance in the remarks by Messrs. Jukes-Browne and Topley on the Purbeck beds (p. 73), I find precisely the opinions put forward with regard to the part played by marine faunas in classification that I have hitherto understood to be generally held amongst geologists throughout the world.

"There can be no question that all breaks in stratigraphy are local, and that such breaks are or may be represented elsewhere by beds. Moreover, local breaks are very often misleading, because the amount of change, and especially of unconformity, is not proportionate to the lapse of time, but depends on phenomena often confined to a limited area, and which may have been of no great duration or real importance. Thus the great break and unconformity between the Coal-measures and Permian in Great Britain is shown to be representative of but little lapse of time by the fact that no change of any importance took place in the marine fauna, the alteration in which between the Carboniferous Limestone that preceded the Coal-measures, and the Permian magnesian limestone, is actually less than that between Devonian and Carboniferous, which are not separated by any important stratigraphical break. If any great lapse of time, or any widespread physical changes, corresponded to the local break between

Carboniferous and Permian in England, it may reasonably be assumed that a great change in marine life would have taken place in the interval.

"The argument to which Professor Hughes naturally refers, that identity of marine fossils in distant localities does not prove synchronism, but rather suggests that the strata were not of contemporaneous origin, as time would be needed for migration, is one on which perhaps too much stress is laid by English geologists. In the course probably of a geological age, certainly of a geological period, there must be ample time for the migration of marine forms, whether pelagic or littoral, throughout all seas that are in connexion. If the marine fauna of the present-day be examined, it will be found that many marine genera, both of vertebrata and invertebrata, are of world-wide range, and that still more are distributed in wide belts stretching round the world. This will be found to be the case with littoral quite as much as with pelagic forms, though there may be more specific variety in the former. Still a host of littoral genera, such as, amongst the Mollusca, *Littorina*, *Patella*, *Purpura*, *Nassa*, *Natica*, *Chiton*, *Mytilus*, *Cardium*, *Solen*, *Mactra*, and *Pholas*, are found on almost every coast in the world.

"Now the identification of the age, or still more of the period, to which a fossil fauna should be referred does not necessarily depend upon all or any of the species being identical with those in a known deposit. Complete identity, when the deposits are far apart, seldom or never occurs except amongst pelagic types, the occurrence of a few identical or allied species, and a similar association of particular genera and subgenera, being the evidence usually adduced in favour of contemporaneous origin. Thus the faunas of marine deposits in America or Asia compared with those of the same geological age in Europe, will be found to exhibit much the same resemblance to each other as do the faunas of the present seas taken from two equally distant parts of the earth's surface. There is one possible exception to be borne in mind. It is probable, though not absolutely proved, that the present temperature of the Arctic regions is much lower than it has been on an average in past times—it is certainly lower than it was in some epochs—and that consequently not only the Arctic fauna, but also that continuation of the Arctic fauna which extends from pole to pole at the bottom of the deep sea, differs more from the tropical and subtropical faunas than has been the case throughout the greater portion of geological time.

"Still, despite this disadvantage, if the living marine fauna of any part of the ocean, including Vertebrata, Mollusca, Crustacea, Echinodermata, Foraminifera, &c., is compared with that of the early Tertiaries (Oligocene or Eocene), a great generic difference will be found, fairly comparable to the distinction between Eocene and Cretaceous life. Comparison of the recent forms with Miocene types would show a distinct, but less well-marked, difference, and if recent and Pliocene faunas were compared, the distinction would be still smaller; but all the newer Tertiaries, commencing with the Miocene, form but one period with recent times, if the marine faunas are taken as the test; and it may be doubted whether the Pliocene could even be separated as a different geological age from the Recent.

"So far I have merely ventured to express a different opinion from Professor Hughes. But on one point I think he is mistaken, and it is very important to call attention to the mistake, because the idea expressed may be widely spread amongst geologists. Professor Hughes says that 'we are every day reminded by the work of specialists that the result of applying the botanical measure often differs considerably from that obtained in the present state of our knowledge from a consideration of the included animal remains. . . . . This does not destroy our confidence in the value of palæontological evidence. We have no doubt that when all the fossil evidence, botanical and zoological, has been adduced it will be consistent.'

"Now I think that it will be found that the real contrast in the indication of palæontological age is not between botany and zoology, but between land or fresh-water faunas and floras on the one hand, and marine faunas on the other. So far as is known, there is not a single well-marked case of the inversion of marine faunas, the only instance of any importance ever brought forward, that of Barrande's colonies, in which an Upper Silurian fauna was supposed to occur in beds intercalated amongst others with Lower Silurian types, having, I believe, been conclusively shown to be founded on a mistake in observation. This fact, the absence of all evidence of inversion, is of itself a proof that similarity of pelagic forms does signify practical synchronism; because, if the similarity implied difference of time due to migration, some cases of inversion

must occur.[1] But in land faunas and floras cases of inversion and of the association of types characteristic of different epochs and even periods in the same beds are numerous. Thus we find the Miocene mammals of the Pikermi beds resting upon Pliocene marine strata in Greece; a Middle Jurassic flora in beds interstratified with others containing a Carboniferous marine fauna in New South Wales; similar strata with Middle Jurassic plants in India overlain by beds with Triassic, and by others with Rhætic plants, and these again succeeded by others with Triassic reptiles; Middle Jurassic plants intercalated between Neocomian and Tithonian beds in Cutch, and Tertiary plants associated in the same strata with Cretaceous Dinosaurs in the Laramie beds of North America. Such cases are explained by the circumstance that the distribution of the land fauna and flora at the present day is very much less uniform than that of the sea; that a terrestrial zoological genus of anything like world-wide distribution scarcely exists; and that even under the same parallels of latitude, amongst the terrestrial genera in America, Africa, and Australia, for instance, only a small percentage are the same, whilst many of the families and some of the orders are peculiar, all testifying to isolation from great antiquity.

"There is, moreover, evidence that the recent fauna is sometimes descended from that which inhabited the tract in Tertiary times, sometimes from an immigrant fauna. Thus, as has been pointed out by Prof. Huxley, by Mr. Wallace, and others, the Mammalian fauna of Central and Southern Africa at the present day is descended from the Miocene (and Pliocene) life of Europe. If a bed were found in Southern Africa containing bones of giraffes and certain antelopes, naturalists only acquainted with European fossil faunas would class it as Miocene (or Pliocene), although it might rest upon strata with Pleistocene marine fossils.

"Again, the recent Mammalian fauna of Australia and New Guinea is Mesozoic rather than Tertiary in its affinities. Nevertheless it is by no means improbable that the gigantic migrations produced by the cold of the Pleistocene epoch have rendered the earth's terrestrial fauna and flora more uniform than was the case in past times; and it may be doubted if anywhere in the world at present there is so wonderful a contrast as that between the Carboniferous flora of Australia and the contemporaneous vegetation of Europe and North America.

"It may be possible, when far more is known than is the case at present, to make out the history of the terrestrial faunas and floras of different subdivisions of the earth's surface. But when the history is known, it is safe to predict, from the little already ascertained, that the tale of the land will not coincide with that of the sea, nor will the story of one terrestrial region be the same as that of another. So far as our present information goes, we must, I believe, in mapping out geological periods and epochs, rely upon what Professor Huxley has called "sea-reckoning" alone.

"4. There is one other feature of each Congress that has hitherto produced a sensibly beneficial effect; this is the exhibition of maps and specimens. This was one of the objects for which the Congress was originally constituted, and one the usefulness of which is unquestionable. At every meeting many geological maps from various countries have been exhibited, and have afforded an opportunity for the comparison of different systems of coloration, signs, &c. Many specimens of general scientific interest, too, have been brought to the notice of those present at the Congress; for instance, the Trilobites and Corals in crystalline schist from Norway, exhibited by Prof. Reusch in Berlin, the Belemnites in metamorphic rock from the Alps, shown by Prof. Heim, and the striated fragments (apparently showing glacial markings) from Carboniferous beds in the Punjab, exhibited by Mr. Oldham in London.

"Comparing the performance of the Congress with the objects of its founders, it may briefly be said that the Congress has succeeded, to a certain extent, in getting together comparative collections, maps, and sections, but that it has not settled many obscure points relating to geological classification and nomenclature.

"There remains one other subject to consider—the probable effect of the Congress upon the progress of Geological Science. This, I believe, has already been much greater than is commonly supposed, but in a direction quite apart from that leading to the geological millen-

[1] This may be shown thus: let there be two areas, one inhabited by a fauna A, the other by another fauna B. Now let A migrate into the area occupied by B, and *vice versâ*. We should then find in the one area B fauna in the upper bed, A in the lower; in the other area A in the upper, B in the lower. Of course the relations would in all probability be more complicated, but the results would be the same.

nium which was anticipated when we should have achieved a uniform geological nomenclature and system of representation by maps. The principal result so far has been the bringing together many geologists from different countries, and affording them an opportunity of becoming personally known to each other. The effect upon the diffusion of geological research, and the consequent reaction of one observer's discoveries upon another who is inquiring into a cognate subject in a distant country, is very great, and is likely to increase. By this means a much greater step will be made towards unification of nomenclature and maps than would result from the appeal to a majority at a Congress.

"Another advantage is the bringing together and publishing the views of different men who have paid attention to particular points connected with the progress of the science. When the views differ so widely as in the case of the crystalline schists, but small progress towards unanimity can be expected; whereas in another matter discussed at the London Congress, the division of the Lower Palæozoic rocks, there was a general agreement as to the partition into three of the Cambrian and Silurian complex, and this really settles the question; for it is evident that on palæontological grounds the lowest division or Cambrian must be classed apart from the other two. There can be no doubt, too, that the wide dissemination of the discussion on a geological question has a good effect, as even if it leads to no results, it produces thought and study in fresh directions.

"I have already expressed my grave doubt as to whether a vote in any Congress can be accepted as the opinion of a qualified majority, and I am inclined to believe that many, perhaps all, of the questions proposed for solution are beyond the scientific range of a considerable proportion of the members. The first objection to the method of voting was that the natives of the country in which the Congress was held outnumbered all others present, and thus, that foreigners, many of whom were representative men, and some of whom were especially sent to represent scientific bodies in their own countries, were hopelessly outvoted. An arrangement adopted at the London Congress will obviate this difficulty in part, it having been decided that whenever a vote is taken the members belonging to the country where the Congress is held and the foreigners shall vote separately, and unless there is a majority in each class of members, the vote shall be null and void. With this improvement a vote may occasionally be taken, but its value, unless the agreement is almost unanimous, will be small, unless the personal composition of the minority is known.

"Membership of the Congress in Bologna was limited to authors of memoirs on geology, palæontology, or mining, university professors, teachers of natural history in public schools and technical institutes, doctors of natural science and mining engineers; but still the opinions of theological, classical, mathematical, or chemical professors on geological nomenclature, or of mining engineers, on the colours to be used in geological maps, could scarcely be considered as authoritative. Where, as in London, the qualification for membership began and ended with the payment of ten shillings, the idea of deciding scientific questions by a majority would have been absurd. As in the case of the British Association, the methods of which are being largely followed by the Geological Congress, the latter must, if voting becomes necessary, select an inner body or committee, and even in a body of experts it must be borne in mind that no one is equally informed in all branches. The opinion of a geologist who has devoted his life to Palæozoic strata would not be of much value if it were sought to draw a line between Eocene and Miocene, and he would be even less competent to decide on questions of petrological nomenclature, whilst a petrologist with a world-wide reputation may never in his life have had to colour a geological map or have thought over the principles involved.

"One good effect the Congress has had already. It has set itself steadily against the adoption and even the discussion of sundry visionary and impracticable suggestions, and the number of these has steadily decreased. An admirable example has been set in the case of what are termed by many geologists homophonic terminations. It was proposed that all names of systems should end in -ic, series in -ian, &c. The proposal found no favour with Teutonic-speaking peoples, and was therefore unsuited for a Congress in which various languages were represented; but it happened to be a favourite project with some of the members of the Nomenclature Committee, and it has consequently been brought forward prominently in the report presented to three Congresses in succession. It is not, I think, likely to reappear."

Tin-mining *in* Mergui District. *By* T. W. HUGHES HUGHES, A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.* (With a plan.)

I.—PREFACE.

Since the publication of Mr. W. T. Hall's Report on Tin-mining in Perak and in Burma, dated the 31st December 1888, to which was attached a fly-sheet by myself entitled *Preliminary Sketch of the Mining Industry of Perak and Burma,* I have been continuously engaged in endeavouring to gauge the physical conditions under which tin ore occurs in the Mergui district and also in setting at rest the misgivings as to whether the present languid character of mining operations is due to the original poverty of the mineral deposits now being dealt with.

I am glad to say that my observations, which are recorded in detail further on, lead me to acquiesce in the views entertained by my predecessors, and, I think, we must seek an explanation in causes other than deficiency and inaccessibility of ore for the feeble tone that marks the mining spirit of the district. Without ore there could of course, be no hope of solid improvement either in the method or amount of work now being carried on, but on this point there is no valid cause of apprehension, and I am sanguine that if the joint recommendations of Mr. Hall and myself are carried out, and if there be no serious fall in the price of metallic tin during the next five years, we shall witness a cheering amendment in the output of our mineral products.

II.—REGISTER OF OBSERVATIONS.

7th January 1889.

Kahan.—Early in January 1889, and so soon as the difficulties had been overcome which usually beset those to whom a country and a language are both new, I started up the Tenasserim river to visit Kahan hill, a classic fragment near Zedawun, situated about 12 miles from the civil station of Mergui, or Beik[1] as it is termed by Burmans. Each of the chief contributors to the literature on the mineral resources of the Tenasserim province—Captain Tremenheere, Dr. Oldham, and Mr. Mark Fryar—spent some little time in the examination of this locality, but the first writer appears to be the only one who entertained a favourable opinion of its productiveness.

Success improbable.

Without entering minutely into the reasons that have influenced my own judgment I am inclined to say that the evidence is not sufficient to justify any vivid hopes of successful lode-mining.

Captain Tremenheere.

Quoting from Captain Tremenheere's report he states :—"This locality appears to be of a very promising description and I have little doubt that, if the work were aided by ordinary skill and means, a tin mine here would be productive. The Kahan hill is, I conceive, an indication of a valuable repository of tin."

Mr. Mark Fryar.

In 1872 Mr. Mark Fryar appears to have instituted a careful series of trial pits and costeaning trenches, and the conclusion he arrived at was that no such thing existed as a vein bearing ore, but

[1] In writing the name is converted into Myeikmyo, a metamorphism that I do not understand, but which my interpreter assures me is understood in Burma.

that a bed of micacious felspar, of from 4 to 6 feet in thickness, occurred near the top of the hill, and that scattered through it were specks of black tin in very irregular and meagre amount. By the disintegration of this bed he thought that some of the ore was freed and small quantities dispersed through the lowland at the base of the hill.

The period since these prospecting operations were brought to a close has permitted the obliterating hand of time to assert itself, and I could see nothing more than vestiges of the explorations that had been carried out. Ranging about, however, as well as circumstances would allow me, and accepting such indications as were *en evidence*, I am of opinion that Mr. Fryar's views are the correct ones.

Prospecting recommended.

Leaving Kahan hill, which is close to the river, and going inland there is a promising spread of country in which I would most certainly recommend search being made for deposits of stream tin that seem to be of almost invariable occurrence in the vicinity of high land. The conditions under which stream tin is known to have its origin imply this of course, and in making the foregoing remark I am stating nothing novel; but it is a significant fact when framing our probabilities and the estimate of our local riches.

Natural advantages of Zedawun.

Zedawun.—The position near and around Zedawun offers great facilities of approach for boats and steamers, and if tin ore should haply be found in paying quantity it possesses all the natural advantages for the establishment of a new town, good river frontage, no foreshore, sweet water, excellent building-sites, and pleasant scenery. Indeed I might parenthetically remark that if the insalubrity of Mergui should necessitate the removal of the civil offices to another locality, Zedawun would be a very eligible situation.

Tharapôn.—The next place visited was Tharapôn, 32 miles from Mergui and situated, like Kahan, on the right bank of the Great Tenasserim. It so happened that I could not see any place where I could conveniently wash for ore, neither could I elicit any information as to ancient or modern workings in the neighbourhood. From the conformation of the ground, however, there is a fair chance of meeting stanniferous deposits, and this statement applies with equal force to localities north and south of the point.

From Tharapôn I had to hurry back to Mergui in order to secure a passage by the S. S. *Mergui* for one of the southern ports of the district. No understanding had been arrived at to enable me to detain the steamer where, for the convenience of my investigations, I might have found it advantageous to do so, and I was dependent on the cordial temper of the commander for such extension of time as he could wrest from his published time-table.

11th January 1889.

Bôkpyin.—Being anxious to inspect some of the mines of the Lenya township I disembarked at outer Bôkpyin, where we cast anchor the day after leaving Mergui. From here to inner Bôkpyin, where there is a police station, the journey had to be undertaken in a disreputable-looking, leaky, and cranky boat obtained as a great favour after an exasperating amount of solicitation.

Not knowing the capabilities of a Burman dug-out I quite expected a catastrophe

before reaching our destination, seeing that the whole of my camp equipage had to be stowed where there seemed room for only a couple of stools and a gun-case. By some art which is a puzzle to me to this day we managed to get under way with all the baggage and, taking advantage of the flood at 4 in the evening, we alternately drifted and paddled up-stream, doing the distance of 7 to 8 miles in something under three hours. We found comfortable quarters for the night at the guard-house, and with the stirring experiences of the afternoon we felt we had earned our rest.

On the morrow and the succeeding day I partly fulfilled the purpose of my trip and saw two of the principal stream workings owned by Sit Sin. There were only five men employed at the time of my visit, but during the rains I was informed that occupation could be found for a much larger number. I was not so concerned, however, with the statistics regarding labour as anxious to satisfy myself that tin ore occurred and that it existed in sufficient quantity to pay for extraction. Both these conditions were amply fulfilled, and I have no hesitation in setting aside as untruthful the statements made to me by the proprietor that it was no longer worth his while to renew the leases which he held. Strong objection was raised to my visiting the mines, and I had to compound my desire for knowledge by agreeing not to go down into the workings, but to be content with skirting their edges and taking a bird's eye view. This limitation was most repugnant to my feelings, but it having been represented to me that the period for the renewal of the mining licenses was just at hand, and that it would be advisable not to disregard prejudices which if offended might lead to the renunciation of all the mining-leases in the district, I grudgingly allowed myself to be swayed. The influence that could be brought to bear on the different proprietors through the power of the secret societies to combine in viewing me as a desolating *nat* was said to be absolute and, as it was of no great moment that I should personally make observation in workings actually proceeding, the District Surveyor (Maung Maung) took the necessary notes.

Tin ore plentiful.

Objection raised to visiting mines.

The superstitions of the Chinese appear to be both numerous and weird, but I am inclined to suspect that many of them are enlisted as safeguards against the interference of Government officials, and the acquisition of information on their part that might lead to the enhancement of the dues already levied from mine-owners.

Superstitions of Chinese.

The ore-bed in the cuttings varied between 5 and 6 feet in thickness and was overlaid by 10 feet of top soil which had to be removed and thrown away as useless. Considerable ingenuity was displayed in the coursing of the drains, so that the full benefit of such natural stream power as existed was obtained without the expense entailed by mechanical appliances. Under these circumstances work must have been carried on very economically and certainly to a profit.

Ore-bed, 5 to 6 feet.

The produce of the different mines in the vicinity of Bôkpyin is all smelted at the furnaces, of which there are two, owned by Sit Sin, a Chinaman. Mr. Mark Fryar refers to one small furnace only in 1871, so that the output of ore has apparently increased at Bôkpyin since his report was written.

Two furnaces.

To show how the industry now stands, I give below a list of workings compiled by the District Surveyor. The nationalities of the various proprietors are indicated, and the number of hands employed during the rains and dry season are given :—

List of mines and mine-owners.

Locality of the mines.	Owner's name.	Nationality.	Number of men employed in: Rains.	Number of men employed in: Dry season.	Ground-rent.	Remarks.
					R	
Bôkpyin creek	Sit Sin	Chinese	32	6	120	
	Sit Hauk		9	2	25	
Lelan Hill	Sit Pôk		28	6	75	Three mines.
Bôkpyin creek	Ashôk Sat		5	...	25	
	Sit Kein		14	...	25	
Bôkpyin	Sit Sein		12	...	25	
Bôkpyin creek	Mi Wun	Siamese	35	7	145	
Wutsan	Pi Than		30	7	110	
Shwe Payôn creek	Mi Kyaw		13	2	25	
Taung Kamit	Hnin Dit		7	...	25	
Kyaung Kinppa	Apyôn		15	...	25	
Kawin south	Hnin Han		12	...	25	
Bôkpyin creek	Awin		6	...	25	
Pit Tauk south	Hnin Pan		3	...	25	
Kôkngôn creek	Mi Shat		4	1	25	
Rytaing	Mi Kyaw		8	...	25	
Bôkpyin creek	Pi Rat		5	...	25	
Wutsan	Nga Dan		7	2	25	
		TOTAL	245	33	...	

Wages not increased.

Wages seem to be the same now as they were a quarter of a century ago, but though greater facilities exist than formerly for procuring labour from Penang, complaints are rife as to the unsatisfactory character of the men who offer themselves. This is an old story, however, and no doubt if the miners were asked for an opinion, they would utter disparaging remarks about their masters.

Ore generally distributed.

I had only two days to devote to Bôkpyin as the S. S. *Mergui* was due on her return voyage after that interval, and consequently a large extent of country could not be covered. It was almost impracticable to leave a track except where it passed through or skirted a patch of cultivation, as the jungle was either too tangled to penetrate or the ground too swampy to walk over, but the evidence of ore was very clear in three or four small streams which were washed, and there is little doubt as to its general occurrence where the physical conditions required are answered.

Jungle dense.

The forest and undergrowth is something marvellous, and unless there are axemen to clear a path by hacking and felling, it is sheer waste of energy and temper endeavouring to force one's way through it. One learns the full significance of the word jungle by an experience of Lower Burma.

From inner Bôkpyin to outer Bôkpyin a road, 3 miles long, has been constructed. This I walked over on my return to the steamer to judge of its present condition and to observe the geological section that it might expose. It requires putting in order, but it will repay expenditure on it, as it is well laid out and is a means of direct and easy communication between the mining district and the sea-board. It might indeed be extended to where the stream works are busiest, but this suggestion may be more appropriately considered when final action in respect to prospecting has been declared.

Road from outer to inner Bôkpyin.

While referring to Bôkpyin I would recommend the erection of a small refuge house for storing Government property and as a shelter in inclement weather.

Refuge house required.

On the 16th January Mergui was reached at 7 in the evening. Here three days were occupied in negotiating the hire of two river boats with the requisite crews, and in the purchase of rice and other stores for my camp, and we again started for the Great Tenasserim.

Tônbyaw.—My first halt was at Tônbyaw, 26 miles up the Tônbyaw creek, a tributary of the Great Tenasserim. Several places were shown to me as having furnished considerable quantities of tin stone during the old Burman rule when tribute had to be partly paid in ore. It is quite possible that my information was correct, but I could not confirm what I heard by finding any myself. Here, however, as elsewhere, deeper prospecting than surface washing may prove the occurrence of mineral deposits. Rain fell heavily for two days.

20th January 1889.

Tin stone formerly worked.

Thabawleik.—On the 22nd I arrived at the old town of Tenasserim, and having made up my mind to see the Thabawleik mines I sought to obtain information from the native magistrate (Myoôk) which might be of use to me. Unfortunately he knew less than myself, and said that he had never had any wish to see them, as they were situated in a wild and dangerous part of the district. An old Mussulman gentleman who had travelled informed me that the Chinese are very averse to anyone, except their own people, going there, and that their *nats* had tigers on the road to waylay the inquisitive and crocodiles in the rivers to bite off the hands of those who incautiously put them into the water. I mention these assurances as another illustration of the superstitions that surround the Chinese.

Ignorance of Myoôk.

Superstitions surrounding Chinese.

Further inquiries at Tenasserim being useless we proceeded up the Little Tenasserim river to the mouth of the Thagyet creek, where we found it necessary to exchange our boats for much smaller ones. We reached the village of Thagyethlèzeik on the 24th January, and then had to make preparations for proceeding overland to the Thabawleik mines. No coolies could be procured for carrying our baggage and the boatmen had to be impressed for this service. They grumbled considerably at doing what they considered was *kulla's* work, and their dignity was very much hurt.

Thagyethlèzeik, 24th January 1889.

The road was represented as being impassable, the distance as varying between 18 and 24 miles, and halting-places as unknown. The truth, as I proved, was that an excellent fair-weather cart track had been cleared by the proprietor of the mines from his works to

Road to Thabawleik, 13 miles.

the river-side, which, shaded by magnificent trees and bamboos, made our march an exceedingly cool and easy duty. Instead of 24 miles the distance was under 13, and the road passes by three small villages and skirts a fine sheet of water adorned with teal and other wild birds.

Lake Htomkha.

The Chinese camp at Thabawleik is placed on the hill-side overlooking some abandoned workings in the bed of the river.

The more recent operations are conducted lower down the stream, and from their size it is evident that, as in Dr. Oldham's day and in Mr. Fryar's time (1871) they are found to be profitable.

Unlike my experience at Bôkpyin no objection was offered to an examination of the mines. I accordingly took advantage of this tolerance, and on measuring the section in the upper cutting found a barren top soil varying in thickness from 6 to 10 feet, and then a strong pebble and boulder bed of slate and sedimentary rocks with highly-charged staniferous clay, 8 feet. Below this I was told no ore occurred, which is the general rule, and may be accepted as true in this case. Quartz fragments are much rarer in the pebble bed here than at Taiping, Renông, and Bôkpyin.

26th January 1889.

Ore bed 8 feet.

The mining of the ore is carried on exactly as described by Mr. Fryar, a suitable place and a convenient width of ground being selected, the non-paying earth removed, and the stream water led in such manner that it economises the operation of excavating and acts as a disintegrator. The miners are principally Chinamen, but there are a few Siamese. The cooly range is a building of considerable size, as it has to accommodate a large number of men working on the co-operative system during the busy season, but it was in a sickening state of defilement.

Mining operations of ordinary nature.

Cooly range dirty.

The ore is smelted on the spot in the ordinary open furnace (about 5 feet high) in use amongst the Chinese. The fuel is charcoal and the air-blast is supplied by a cylindrical bellows fitted with a piston and worked by manual power.

Furnace.

In endeavouring to arrive at an appreciation of the wants and wishes of the mine-holders I had a laboured conversation with the Resident Manager, Sit Saw, through the medium of the District Surveyor, who acted as interpreter. The difficulties he had to contend with, he said, were want of capital, want of water, and inability to control refractory coolies. There was no deficiency of ore. There were reserves lower down the valley in which they were located; and they have prospected and found tin stone in other places adjacent, both on this side and on the other side of the hills on which their camp is pitched. As to the *want of capital,* this appears to be the normal condition of every Chinaman whom one addresses, and must be accepted with such reservation of belief as one entertains in the truthfulness of the speaker. The term as implying restriction of development owing to limitation of means is perhaps applicable to every undertaking, but it is too often urged to cover errors of commission and omission. This much appeared clear, that the present lessee of the Thabawleik mines had no wish to open out extensively, as

Difficulties complained of.

by so doing others might be attracted to the district and conflicting interests arise showing little respect for the prescriptive rights that his long tenancy has enabled him to claim.

Want of water was true only in the sense that sufficient means had not been adopted for controlling the resources they had in such manner that operations might be carried on throughout the year, or nearly the whole of the year. This difficulty has been met and practically overcome in the mining districts of Perak by the introduction of steam power, and the same measure might be adopted here.

Refractory coolies.—There seems to be fair ground for complaint under this head. An intractable cooly or a malingerer, or one who deserts, is a perplexing fellow in the absence of facilities for enforcing the obligations of his contracts. The evidence of such law as exists is too far removed to have any moral effect, and the application of it is too tedious a process to indulge in. Examples of successful insubordination demoralize the other workers. The malingerer invites imitation and the deserter is usually a loss in money as well as of labour. The remedy, I presume, is a more effective act which will protect the interests of employers.

Tagu, 2nd February 1889.

From Thabawleik I returned to Tenasserim and proceeded up the Great Tenasserim river as far as Tagu. Examining such intermediate localities as were accessible, namely, Banlaw, Wunna, and Thamihla, I obtained no indication of tin stone, but this is probably due to the very little time that I could spare for investigation at each place.

Captain Tremenheere in his report of 1841 mentions the discovery of several old pits above Tagu, and this is evidence enough that tin ground occurs. Messrs. Melosch, Holman & Co., also carried on work for a short time at Theindaw.

Wish unfulfilled to explore upper valley of Great Tenasserim.

Had leisure offered it was my intention to have explored the whole length of the Great Tenasserim valley as far as the boundary of the Tavoy district, but I had to prepare immediately for the downward journey to Mergui to again take advantage of the opportunity afforded by the monthly steamer of reaching Victoria Point, and thence going up the Pakchan river whilst there was enough water to bear me to the Banhuni [1] mines, which had the reputation of being the richest in the Maliwun township. There was a further inducement to visit them in the fact that they had never been reported on by any of my literary predecessors, and that nothing very definite was known about them.

Banhuni.—As difficulty was anticipated in procuring transport, the Deputy Commissioner (Colonel Alexander), who had some extradition cases with Siam to inquire into, proposed accompanying me as far as Nalingsan and seeing that the necessary arrangements were made for furthering my object. We quitted Mergui on the 7th February and reached Victoria Point and Nalingsan[2] (where the circuit-house of the Pakchan district is situated) five days afterwards. Mr. Leslie, Inspector of Police, who had been attached in that capacity for the last quarter of a century to the Maliwun frontier guard, and whose knowledge of the country is unique, was placed in

Mr. Leslie, Inspector of Police.

[1] Ban = village, hu = ear, ni = gibbon.

[2] Pronounced and written Nalingchan in Siamese. Na = field, ling = steep, chan = bank.

charge of my party. Through his influence with the Siamese, who regard him as *de facto* representing British rule, the necessary number of light-draught canoes and their crews were secured. The boats required four men each to handle them as there were known to be a succession of shoals and rapids through which they would have to be pushed or over which they would have to be carried; and, further, we had the current to contend with for nearly 60 miles. The racing canoe of Nalingsan, so nicely balanced that it accepted the slighest excuse for canting, was set apart for my use; Mr. Leslie occupied another. The provisions were placed in a third, and two policemen and two servants who could all row had a fourth. With this fleet we got under way at daybreak on the 14th, and passed the last sign of habitation at Lonpaw, 10 miles beyond Nalingsan. Thence to Banhuni the course of the river was through an almost unbroken stretch of forest and of silence. Our crews showed a spirit that amazed me after the disparaging remarks I had heard of Siamese activity and energy, for they plied their paddles and their oars steadily until we had covered 29 miles. We rested for the night on the Klôm[1] sandbank and ran up a slight screen of bamboos and leaves as shelter against the dew. It was good enough for the purpose it was intended for, but unfortunately we were overtaken by a heavy downpour of rain and as a consequence of getting wet, I had a touch of my old enemy,—gout.

Preparations for journey to Banhuni.

14th February 1889.

Halt at Klôm sandbank.

On the following morning the men breakfasted before starting. By allowing them to do this they were fitted to keep steadily at work the whole day. They had a very rough task, jumping in and out of the boats times innumerable to lighten them, then guiding them through swirling rapids, avoiding dangerous juts of rock, and dragging them over shoals that multiplied in number as the day wore and when their exertions had begun to tell on their endurance. The last 10 miles after entering the Banhuni stream, which we recognized by its discoloured water, were very trying, and to my inexperienced eye it seemed an impossibility that our boats could make any progress amongst the detached blocks of rock, fallen trees, and snags that barred our way. Mr. Leslie, however, made light of my misgivings, and as evening fell I was glad to see that Banhuni was reached and that our men's labours were over.

The mines big and small at present worked are seven[2] in number, owned by the undermentioned proprietors, who employ between them about 200 men, Chinese and Siamese:—

Banhuni mines.

Proprietor.	Number of men employed in the rains.
Meng Hong	120
Nu Noi	4
Chen Tain	7
Chek Yôk	6
Chek Hoe	4
Chek Pein	3
Chek Wan Chu	3

[1] Klôm, the name of a murdered man.

[2] In the Akunwun's office the returns give 22 mining licenses for 1888-89. I can but repeat what was told to me. My acquaintance with the Siamese language is summed up in the words 'go on' and 'water.' I am most positive Mr. Leslie said that seven mines only were in progress and I entered that number in my note-book.

They have been opened out in the land lying along the base of the Banhuni range of hills where the conditions are exceptionally favourable for the Chinese system of working. There is a very full supply of water, and the ore-bed is 6 to 8 feet in thickness and of sufficient richness to repay the trouble of getting it. The locality well deserves the reputation that it possesses, and it is capable of considerable development. Here, as at Bôkpyin, I was asked not to go into the cuttings, but at the same time I was informed that, if I wished to disregard the request, no opposition would be offered. As I was anxious to be on good terms with the people and to encourage them to express their views freely with regard to tin, I thought it politic to fall in with their desire and, for the second time, I gave way to superstition.

Favourable conditions for mining.

Ore-bed 6 to 8 feet.

Superstition.

On this occasion Mr. Leslie was my interpreter and conversation was carried on in Siamese. I inquired why objection was raised to my inspecting the workings, and the reply was that the guardian spirit of the mine would be offended if any one trespassed on the limit of his watch who failed to pay him respect, and as it was not expected that I would either offer joss-sticks at his shrine or doff my shoes to him, the best course was for me to pass by and not hurt his feelings. Any falling off in the outturn of the mine, any calamity arising from sickness, or any unusual occurrence would be ascribed to my want of reverence by the coolies; and the managers said they would certainly have trouble with their men.

Of the advisability of a labour law there was but one opinion amongst the employers, and they asked that the same rules as those prevailing at Renông might be introduced. I believe, however, that the amount of arbitrary administration which is there exercised could scarcely be permitted in English territory, but we might well take the regulations sanctioned in the Perak State as our standard.

Labour law wanted.

As to roads they were somewhat indifferent, the Pakchun river affording them passable communication with Maliwun, Victoria Point, and Renông for eight months in the year during which time they could transport their supplies. A bridle-path, however, to Karathuri would give them another point at which to reach the sea-board. I finally alluded to the interests of Government, and inquired whether they considered it fair that they should have license to mine and deport tin from British territory without paying anything in the shape of duty or royalty. The answer was that the Siamese Government would not allow them to do so, but the English Chief Commissioner had seen how poor they were and was very sorry for them.

Bridle-path to Karathuri.

Taxes.

The largest employer of labour and the most successful mine-owner is Meng Hong, a Siamese Chinaman living at Kra, and it certainly struck me as anomalous that Siamese subjects should be allowed to invade English territory, take our tin stone (depriving us of resources that can never be replenished), cut down our trees, waste our lands, and subscribe nothing to our revenue. There is no reason why the ordinary dues should not be levied. The mines at Banhuni are the richest in the whole district of Mergui.

Dues should be levied.

There is probably always an argument in favour of remitting heavy imports or modifying them as circumstances may dictate; but where the trifling claims of Government are found to be a withering burden I think the time to close such mines has arrived, for every acre of land converted into a spoil-heap is rendered useless for cultivation, and neither miner nor husbandman nor the administration is benefited.

If ordinary dues retard, mines should be closed.

The policy of not levying a cess of some sort is wrong as it is the visible sign of the paramount landlord. In a few years every squatter at Banhuni will deem himself the proprietor of the mine he works and of the ground his house stands on; and any attack on his customary immunity will be considered a breach of faith.

Policy wrong.

Sickness amongst the coolies is said to be very general, fever and skin affections being the most prevalent maladies. Both these diseases will probably exist where so many hardships as those incidental to mining have to be endured.

Sickness prevalent.

A miner's life is not an enviable one. In pouring rain and sun, alternately wet and dry, he has to work ankle-deep in slush and water. His food is a constant repetition of rice and salt-fish, interrupted on feast-days only by pork rarely garnished with vegetables. The water he drinks is good or bad as the case may be. He is usually a newly-arrived immigrant. The recollection of his old home is still with him. He has no woman's society. There are no public diversions, and he is encouraged, in the pecuniary interest of his employers, to seek joy in opium, fire-water, and gambling. He becomes lowered in body and mind, more susceptible to disease, and when overtaken by it is less capable of fighting against it. Some of the abscesses on the legs of the coolies at Banhuni were frightful sores, and itch and scurvy had attacked at least 30 per cent. of the men I inspected. The cooly ranges were filthy inside and the uncleanliness outside was worse. Men defecated their persons where they pleased from the threshold of the house to the edge of the gutter holding their drinking-water.

Miner's life not an enviable one.

Cooly ranges filthy.

Despite a storm brewing the night I stayed I preferred again getting wet to breathing fecal-burdened air, and I declined the invitation of the Manager of Meng Hong's mine to take shelter in the range.

Our return journey with the current in our favour was a moderately easy task; but for the benefit of those officers who may be desirous of going to Banhuni I would warn them not to attempt it after the month of February, as the water in the river falls too low for the passage of canoes. If I understand Mr. Leslie aright, bamboo rafts are used during the dry season, as the owners of boats are unwilling to subject their property to the heavy wear and tear of being dragged through shoals and of being bumped and knocked about in the rapids.

I was glad of a rest at Nalingsan to doctor myself for gout and to get rid of the stiffness induced by having to sit or, more rightly speaking, balance myself for twelve hours every day on a narrow boat's thwart.

Nalingsan.

Before ending this reference to my Banhuni trip I wish to acknowledge Mr. Leslie's services. I am told that he is thoroughly acquainted with the whole of the Mergui district, and, if any prospecting parties are organized, he would be a very fit officer to place in charge of one of them. In addition to English he speaks Burmese, Siamese, Chinese, Malay, and Karen; all of which are necessary as mediums of communication,—English and Burmese for official purposes, Siamese and Chinese amongst the miners, Malay for the islands of the Archipelago, and Karen amongst the hill tracts bordering the Great and Little Tenasserim rivers.

Mr. Leslie qualified to take charge of a prospecting party.

To reach Mergui we availed ourselves of the S.S. *Zephyr* on the 22nd February and on the voyage we called at the Marble Islands. They are a small group of detached islets and chiefly valuable for the edible birds' nests that are gathered in the caves formed in the limestone of which they consist. Our run occupied only two days, as we put in at none of the intermediate ports visited by the S.S. *Mergui.* I found orders awaiting me to hold myself in readiness to proceed to Rangoon and possibly Calcutta, which were afterwards modified to go to Rangoon and then cancelled. Before I could act on the last decision, however, I had started in the mail-boat *Avagyee.*

S.S. *Zephyr,* 22nd February 1889. The Marble Islands.

Orders to proceed to Rangoon, 1st March 1889.

Karathuri.—It was not until the third week in March that I was able to resume field-work by availing myself once more of the S.S. *Mergui.* In the meantime I had coached the District Surveyor in a little geology and taught him how to distinguish tin stone; and a small prospecting party, of which he was to have control, was organized for the double purpose of looking for tin and tracing a route between Karathuri and Bôkpyin, and Karathuri and Banhuni, which I consider essential for the welfare of the mines. With a Siamese interpreter, two chainmen, two washers, and two policemen, kindly placed at my disposal by Mr. Law, District Superintendent of Police, we left Mergui for Karathuri, making our point of disembarkation (called Kyinmezeik) on the 24th March. It is a rocky promontory (dividing the Karathuri and Chaungtaung creeks) with a small cluster of fishermen's huts on it, which were deserted when we arrived. By good fortune we discovered a canoe that with patching was made sufficiently water-tight to enable the District Surveyor and a policeman to reach the Karathuri mines. With the additional help of two more boats we compassed our purpose of getting to Karathuri on a neap flood in two hours and a half. This includes the time occupied in walking a mile in the bed of the creek, as there is only water enough to float boats to the mines during spring tides.

Prospecting party organized.

Kyinmezeik, 24th March 1889.

Journey 2½ hours from Kyinmezeik to Karathuri.

I found everything nearly on a pattern scale and a considerable change must have come over the fortune of Karathuri since Mr. Mark Fryar visited it in 1871. For, writing in that year, he states:—"The yield of mineral has fallen off in recent years, and in the village where formerly there appeared to have been a considerable population no more than five houses are now occupied. From what can be seen from simple

Improvement of mines since 1871.

inspection of the places for tin-washing there is an evidence of poverty in yield of the mineral as compared with other places under examination."

The picture is a very different one now; men were busily employed in stripping fresh ground and in working standing-places. The ore-bed in one mine was 8 feet and in another 12 feet thick, of good paying character, and the supply of water was fairly abundant. The coolie range was neat and clean with a palisade around it. A guest-house stood in one corner of the compound, and a lofty shed covered a furnace in which the ore raised was smelted. The store-room was well filled, and on all sides the evidence denoted prosperity.

Ore-bed 8 to 12 feet.

The cooly range neat.

Furnace.

The lessee, a Chinaman named Sit Pu Shein, was absent, but his wife, Ma Chit Thu, an intelligent and affable Burmese lady of 37, very readily gave me all the information I wanted after assuring her that I had no wish to injure her interests, which I practically proved by acceding to her request not to go down into the workings they were newly opening. She quoted the prevalent belief of the Chinese in the sinister influence of European disregard for the sanctity of their ruling spirit, and told me that a most auspicious destiny for the new mine had been secured by the slaughter of a buffalo. With the object which has constantly been kept in view of fathoming the requirements and needs which, if supplied, might beneficially affect the output of tin, I closely interviewed Ma Chit Thu.

Burmese lady communicative.

Superstition.

It appeared that next to lack of capital the sorest point was the desertion of coolies. She said there was no remedy against this nuisance. If instances were reported at the police station of Bôkpyin, the sergeant made a note of the complaint and humorously advised them to catch the runaways that he might send the cases to Mergui for trial. Under the most favourable circumstances this would involve such an expenditure of time and money that employers were practically debarred from taking any action and they had to resign themselves to the situation. An English Magistrate at Bôkpyin, she thought, would be a boon, as a Burman was too lazy and indifferent.

Desertion of coolies.

English officer wanted.

On the subject of roads she was very eager that Karathuri should be brought into easier communication with Chaungtanaung and Banhuni on one side and Bôkpyin on the other, more especially, however, with the latter place. Coolies, she told me, could be obtained with ease in Penang for any kind of labour, and she showed me the form of agreement that the men had signed at the offices of the Chinese Protectorate in Penang. Somewhat to my astonishment I read that all the coolies had engaged for plantation work at Kopa. I do not understand the reason of this diplomacy unless it be that wages are less at Kopa than they would be for employment in British territory. The salary was entered at \$42 a year of 360 working days. An advance of \$19·50 had to be made repayable at \$1·62½ cent per mensem. Food free and, in case of sickness, 30 days in the year allowed. I am informed by Mr. Trautmann, the purser of

Roads.

Coolies procurable in Penang.

Terms of engagement.

the S S. *Mergui*, that they have conveyed coolies brought direct from China, whose wages were $25 a year instead of $42. This seems very low remuneration, and I repeat it on the authority of my informant.

Chaungtanaung.—To the south of Karathuri, about 5 miles by land, is the mining circle of Chaungtanaung that has seen better days. There is only one working registered, but in the course of his prospecting, the District Surveyor tells me he came across places where poaching was evidently carried on in the rains. Setting aside the illegality of this proceeding it was satisfactory to obtain confirmation of the occurrence of ore.

Mining decay.

The lessee of the Chaungtanaung mine is Maung Mè, a son of the late Set Shan, who once rented the whole of the Maliwun township from Government. He appears to be in straitened circumstances and employs only four coolies. The stanniferous stratum is not more than 3 feet, and is said to be poor in quality. No work was going on, and the inhabitants of the village seem to derive more profit from the produce of their gardens, for which they have a sale at Karathuri, than from tin-streaming.

Ore-bed.

On the 27th the steamer picked me up, but Maung Maung and his men were left behind to trace, as I have mentioned above, a route to Banhuni and Bôkpyin, and to report any finds of tin.

27th March 1889. Prospecting party for Banhuni.

My attention was next directed to the islands in the vicinity of Mergui; and in anticipation of threatening weather, which was realized, arrangements had to be made for engaging a better class of boat than we had previously hired. A week passed before we could meet with one, but eventually a light kattoo (belonging to the thugyi of Ye-e circle[1]), with a plank-roof cabin, was secured; and on the 7th April we started for Tailangsaing, Tawnaukli, and the southern branch of the Great Tenasserim. I found when too late that the boat was too heavy for the crew when the breeze was against us, so that we had to work entirely with the tides.

Island near Mergui.

Sea-boat required. 7th April 1889.

Yamon.—I landed at Nauklè, Pèya, and elsewhere, and attempted to get as far as Yamôn, but there was not water enough in the creek leading to the latter place and I returned to Mergui to wait for a spring flood.

The Yamôn mines are the only ones in progress within the Mergui township, and though their output is insignificant, their position on the answering side of the range of hills bounding the valley of the Tenasserim river is an interesting proof of the occurrence of tin deposits where one would have expected from general reasoning to find them.

With more efficient means than at my last essay I reached Yamôn on the 16th April. There was nothing doing at this time of year, but in the rains streaming is carried on at three places on a limited scale. The ore-bed where I examined it varied from 2 to 3 feet in thickness, but further prospecting should be encouraged.

Ore-bed 2 to 3 feet, 16th April 1889.

The ore is taken to Pyinngè near Zedawun to be smelted, where the lessee of one of the mines, a Yan Shôk, has his family home.

Furnace at Pyinngè.

[1] Ye-e is an island circle of the Mergui township.

On the 19th I made my last voyage to the south to receive the District Surveyor's report of progress and to inspect the Yengan and Sadein mines. At Bôkpyin I obtained intelligence from the Myoôk that all the members of the prospecting party had been invalided by fever and were on their way back to Mergui. He said they had suffered great hardships, owing to having no shelter when overtaken by rain and that their legs were covered with sores.

Last voyage southward. 19th April 1889.

The mines at Sadein were too far off for me to visit them in the time the captain of the steamer could spare for the purpose; but those of Yengan were within an easy pull of the ship's boat, and I visited them with Captain Sheldrick[1] as a guide. They presented no novelty and were deserted for the season.

Sadein and Yengan mines.

In Mr. Fryar's time no furnace existed at Yengan, and the ore was sold at Bôkpyin. This want has now been supplied, and the tin stone is smelted on the spot. The names of lessees and the number of men employed on the different working are as follows:—

Furnace at Yengan.

Locality of the mine.	Owner's name.	Race.	Number of men employed in Rains.	Number of men employed in Dry season.	Ground-rent.	Remarks
					R	
Yengan creek	Maung Shwe Thaw	Chinese	8	...	25	
	A. San Shôk	Do	6	...	25	
Kawin south	Nga Pyan	Siamese	5	...	25	
Munanôn	Maung Hmo	Burmese	8	...	25	Migyaung-chaung.
Munthôn	Pi Nu	Siamese	20	3	50	
		Total	47	3	...	

We reached Mergui on the 26th, and as the Commissioner of the Division, Colonel Plant, was expected for the Sessions, I waited that I might call upon him and secure the benefit of his knowledge of the requirements of the district, which I have found of great value in framing my summary. After his departure for Moulmein I made a traverse of the Tanyet Circle, and toward the close of the month went to Pawa to test the accuracy of a reputed discovery of ore.

Interview of Colonel Plant, Commissioner, Tenasserim Division, 2nd May 1889.

Mazaw.—No mining is carried on in the Tanyet circle, and I neither saw nor heard of any old workings, but I am of opinion notwithstanding that tin will be found if the country be inspected at Mazaw. The physical consideration is very suggestive, and there is a closer imitation in outline to Taiping and Renông than I have seen in any of my wanderings.

Probable occurrence of tin stone.

Maliwun.—The mines at Maliwun have the widest reputation of any in the Mergui district, and the quality of the ore they yield is said to be better than that of Renông. The licenses issued fo-

Quality of ore good.

[1] Commander of S.S. *Mergui.*

work during 1888-89 under the head of Maliwun are said, according to information derived from the Revenue Office by the District Surveyor, to be 163. The Deputy Commissioner, to whom I applied for an explanation of what struck me as a very large number of applications, states :—"In reply to your letter about mining statistics in Maliwun, I find from the Revenue Office that there are five mines in Banhuni and twelve at Maliwun. These were not rented, but were worked in 1888-89 by 183 men on individual certificates without payment."

Maliwun township leased from 1873 to 1877 by Messrs. Strang, Steel & Co.

Maliwun possesses a melancholy interest from the circumstance that it has been the scene of an abortive attempt on the part of a large English firm to carry on mining. It is said that "the firm made the mistake of importing Bengal[1] coolies who understood nothing of mining, and made a second mistake in attempting to work the veins. After three years of hard work, and after upwards of three lakhs of rupees had been spent, they resigned their lease."

Maliwun township repay prospecting.

I assume that costly supervision and unnecessary plant may have added to the difficulties of the enterprise. Notwithstanding this disastrous experience I think the Maliwun township will well repay prospecting. I cannot persuade myself that its resources are exhausted.

This brings the detailed record of my observations to a close. There has necessarily been a great deal of repetition, as one place is very like another and one mine is a copy of its neighbour, but throughout my record of inspection I was always buoyed by the hope that some item having a useful bearing on the main inquiry might crop up.

I claim no credit over my predecessors Dr. Oldham and Mr. Mark Fryar. Both appear to have effectively done their work so far as their opportunities allowed; and had they possessed such a standard of comparison as the Perak State, they would doubtless have been able to suggest remedial measures which long ere this would have borne fruit.

Occurrence of ore widespread.

They pointed out the widespread existence of ore, which I can fully corroborate, and they bore testimony to its high quality and freedom from injurious ingredients.

Dr. Oldham's opinion. Ore abundant.

Dr. Oldham in his paper says :—"The principal source of the ore is the extensive deposit of stream tin where the degradation of the previously existing source has produced a detritic gravel, broken up and washed down the slopes of the higher ground and accumulated in all the flats and stream courses." And in summing up he expresses astonishment that such valuable deposits of ore should have been neglected by Europeans. This was in 1855, or 34 years ago.

Mr. Mark Fryar's opinion. Ore abundant.

Mr. Mark Fryar, declaring his opinion, writes :—"It may be advisable for me to state generally the opinion I have formed as to the mineraliferous localities in the vicinity of Mergui. What strikes me as being the most remarkable feature as to the mineral of such localities, is the *wonderful* extent of the distribution of stanniferous detritus. In rivers on the mainland and on islands of the sea every small dishful of

[1] Madras.

sandy gravel taken up contains palpable traces of black tin stone." This was in 1871, or 18 years ago.

III.—DEVELOPMENT.

Mining progressing in other countries.

That the progress of mining in this district during the past 15 or 20 years have not answered to the expectations formed of it is a circumstance well known to Government, and I need not waste time in empty remarks about want of enterprise, lack of energy, and so on. The fact is patent that we are stationary, while other countries are pushing on and bringing ever-increasing revenue to their treasuries. Concessions are being granted and companies formed in the states of the Malay Peninsula, while there is not one single inquiry for an acre of land where our rule has been established for 60 years, and where the occurrence of tin-ore has been published to the world time after time. Why is this, and what measures should be introduced for bringing about a change?

Mr. Hall's views clearly and forcibly expressed.

Mr. Hall's views have already been published, and they embody so many of my own impressions that I feel at a disadvantage in repeating much of what has already been so clearly and forcibly expressed, but there are a few points that I would emphasize and one or two that I would suggest.

As we cannot rush to a perfected condition of prosperity, I think we may advantageously divide our efforts into those on which action should be first taken and those which may be subsequently carried out, and the initiatory steps that I recommend are—

(*a*) prospecting and placing of ore;
(*b*) circulation of the facts thus obtained and publication of mining terms;
(*c*) alignment of bridle-paths;
(*d*) survey of the Mergui district.

(*a*) By prospecting I mean a much more searching investigation than any heretofore undertaken, one which will give us *official assurance* of the full estimate of any selected localities looked at from a miner's point of view. Their accessibility, their ore-bed, and their supply of water should be appraised by our own officers; and when these are satisfied that with ordinary means and suitable appliances success may be guaranteed, the pioneer adventurers can be invited to come up and take possession of the lands. This is no policy of offering bait, but rather the exercise of common care that the object for which we are striving should not be damned by failures that may create an utterly erroneous impression of the resources of this district.

I am strengthened in the recommendations embodied in the above paragraph by the emphatic advice of Sir Hugh Low, who said that whatever measures were contemplated for introducing or attracting Chinese labour to Burma for mining purposes, it was essential to guard against the repentance of those who first embarked their capital, and nothing would so effectually parry this as close and accurate prospecting beforehand.

We have the promise of the Resident that if the terms which the Government of India might be inclined to offer Mr. Scott, the Inspector of Mines for Larut, be acceptable to that officer, he would sanction his deputation on foreign service for a while as a prospector. Apart from Mr. Scott's practical knowledge, his personal acquaintance with the large mine-owners of the Perak State is a valuable factor in a scheme of development.

On the 1st January 1889, in an official communication to Mr. Hall alluding to a prospecting establishment, I recommended that Mr. Scott should be engaged for two years, and that an assistant prospector should be appointed with the possibility of permanent employment in case Mr. Scott reverted at any time to his original post. Three sub-prospectors and twenty miners were to be enlisted, and two interpreters and five peons. The grant for this establishment[1] was estimated at R2,495 a month, as follows :—

		Rate per mensem. R	R
Mr. Scott	Salary	500	650
	Field allowance	150	
Assistant Prospector (Englishman)	Salary	300	450
	Field allowance	150	
3 Sub-prospectors (Chinese)	Salary	100	300
20 Miners (Chinese)	Wages	30	800
	Maintenance	10	
1 Interpreter (Siamese)		60	110
1 Interpreter (Burmese)		50	
5 Peons		15	75
Stationery and Postage			10
Contingencies (medicine, huts, &c.)			100
	TOTAL		2,495

Boring apparatus and a couple of Norton's tubes and petty tools and cradles, basins, surveying instruments, transport and joining fares, would be covered by a trifling sum of R3,000.

I think a hospital assistant should be attached to each party, as outside of the civil station there is not a medical officer in the district. Some of the men will undoubtedly be struck down by sickness, and if there be no present help, they will probably have to be invalided to Mergui, or they will lose heart and desert.

In pointing out the necessity of State prospecting I do not mean that private prospectors should be discouraged. Disappointment at not finding tin stone in some gulley is a small matter. What we have to heed is impulsive mining on insufficient evidence.

(*b*) The circulation of the facts ascertained by prospecting should be made as wide as possible, and a quarterly return of work might be published in all the local Gazettes of India, those of Penang and Perak, and in the English Mining Journal. At the same time the terms on which leases or concessions are available might be added. These should be of the tenor of those[2] that have been found to answer in Perak and with which the Straits Chinese are familiar.

[1] Three blacksmiths and bellows-boys and three carpenters ought to have been added.—16th June 1889.

[2] The forms are printed as appendices to Mr. Hall's Report.

I am of opinion that Government should derive some revenue in the shape of royalty, and to this form of tax the Chinese appear to have no objection. Five per cent. on the market value of metallic tin would be a very light impost. In the Perak State an export duty is charged in place, I believe, of royalty, and in December 1888 this was equivalent to about R150 per ton of metallic tin.

(*c*) The alignment of bridle-paths between the principal mining camps should be commenced without delay, and their construction as soon as estimates are framed and sanctioned. The almost total absence of roads in the Mergui district strikes me forcibly, but I presume the very free communication by water and lack of funds have retarded engineering efforts in this direction.

If, however, the country is to be opened out, and if mining is to prosper, there must be some roads to and from certain main points. At present I recommend bridle-paths on the score of economy, which eventually can be widened or improved.

The following are the ones most necessary:—

(1) Maliwun to anchorage of S.S. *Mergui;*
(2) Maliwun to mines in its neighbourhood;
(3) Karathuri to Bôkpyin;
(4) Karathuri to Banhuni;
(5) Outer Bôkpyin to mines of inner Bôkpyin.

The pages of the *Perak Gazette*[1] bristle with references to the want and the utility of ways of communication, and I need only quote one passage from the report of Mr. E. J. Bunster, Acting Collector and Magistrate of Kinta, to show the value that Sir Hugh Low, the Resident, attaches to them: "The chief result of this visit was that the Resident sanctioned an expenditure (not in the estimate for 1887) of $4,600 to make a bridle-path from Tamboom to Cho and Tanjong and Rengkeng with a view to tapping further valleys containing tin." To make roads we must have money, and to make money it appears we must have roads.

(*d*) Next in importance to the step I have suggested in the preliminary portion of my scheme is a survey of the Mergui district.

In the course of the general survey of the Indian Empire, the Mergui district will of course be embraced by it, but if the request be not an impracticable one, I would ask for the concession of any early advance of its operations in this direction. The present maps of the district are mere riddles for anxious inquirers.

In the second stage of development, assuming that the result of our preliminary endeavours justifies a belief in ultimate success, and admitting that we have to look mainly to an influx of Chinese to supply the requisite labour, it will be advisable—

(*e*) to consider whether a labour law should be passed;
(*f*) to frame special regulations for a Chinese mining population;
(*g*) to appoint special officers, one for Chinese affairs and one for mining interests;
(*h*) to improve communication by land, river, and sea;
(*i*) to increase or modify the administrative staff of the district;
(*j*) to ensure the sympathy of every officer.

[1] The *Perak Government Gazette*, dated 22nd February 1889.

List of Tin Mines in the Lenya Township.

Locality of the mine.	Owner's name.	Race.	Number of men employed in: Rains.	Number of men employed in: Dry season.	Ground rent.	Remarks.
Bôkpyin Circle.						
Bôkpyin.					R	
Bôkpyin creek	Sit Sin	Chinese	32	6	120	
Bôkpyin creek	Sit Hauk	Chinese	9	2	25	
Lelan Hill	Sit Pok	Chinese	28	6	75	Three mines.
Bôkpyin creek	Ashok Sat	Chinese	5	...	25	
Bôkpyin creek	Sit Kein	Chinese	14	...	25	
Bôkpyin creek	Sit Sein	Chinese	12	...	25	
Bôkpyin creek	Mi Wun	Siamese	35	7	145	
Wutsan	Pi Than	Siamese	30	7	110	
Shwe Payon creek	Mi Kyaw	Siamese	13	2	25	
Taung Kamit	Hnindit	Siamese	7	...	25	
Kyaungkinpya	Apyon	Siamese	15	...	25	
Kawin south	Hnin Han	Siamese	12	...	25	
Bôkpyin creek	Awin	Siamese	6	...	25	
Pittauk south	Hnin Pan	Siamese	3	...	25	
Kôkngon	Mi Shat	Siamese	4	1	25	
Rylaing	Mi Kyaw	Siamese	8	...	25	
Bôkpyin creek	Pi Rat	Siamese	5	...	25	
Wutson	Nga Dan	Siamese	7	2	25	
	Total	...	245	33		
Sadein.						
Sadein creek	Tha I Kit	Siamese	16	2	50	
Sadein creek	Mi Ket	Siamese	19	4	90	
	Total	...	35	6		
Karathuri.						
Karathuri	Sit Pu Shein	Chinese	90	35	100	Three mines.
Kyaukkyi creek	Sit Pu Shein	Chinese	25	4	25	
Kyaukkyi creek	Kunhein	Chinese	12	3	25	
	Total	...	127	42		
Lenya Circle.						
Yengan.						
Yengan creek	Maung Shwe Thaw	Chinese	8	...	25	
Yengan creek	A San Shôk	Chinese	6	...	25	
Kawin south	Nga Pyan	Siamese	5	...	25	
Munanôn	Maung Mo	Burmese	8	...	25	Migyaung-chaung creek.
Munthon	Pi Nu	Siamese	20	3	50	Migyaung-chaung creek.
	Total	...	47	3		
	GRAND TOTAL	...	454	84		

MAUNG MAUNG,
District Surveyor, Mergui.

List of Tin Mines in the Mergui Township.

Locality of the mine.	Owner's name.	Race.	Number of men employed in: Rains.	Number of men employed in: Dry season.	Ground rent.	Remarks.
					R	
Shweat creek, Ya-mon;	Ayan Shôk . .	Chinese	5	...	25	
Yamôn creek . .	Anwi Shôk . .	Chinese	4	...	25	
		TOTAL .	9	...		

Tin Mine in the Tenasserim Township.

Locality of the mine.	Owner's name.	Race.	Number of men employed in: Rains.	Number of men employed in: Dry season.	Ground rent.	Remarks.
					R	
Thabawleik . .	Maung Shwe O. .	Chinese .	60	7	125	Two mines.

List of Tin Mines in the Maliwun Township.

Locality of the mine.	Owner's name.	Race.	Number of men employed in: Rains.	Number of men employed in: Dry season.	Ground rent.	Remarks.
	Sit Pôn . . .	Chinese	16	...	No ground rent is levied in the Maliwun township.	The list of mines in the neighbourhood of Maliwun town is incomplete.
	Sit Saw . .	Chinese	20	...		
	Sit Lown . .	Chinese	22	...		
	Sit Lu . . .	Chinese	4	...		
Maliwun . .	Sit Kwai . .	Chinese	3	...		
	Sit Kwan . .	Chinese	4	...		
	Saw Taung . .	Chinese				
	Sit Hwat . .	Chinese	4	...		
	Sit Ban . .	Chinese	6	...		
	Meng Hong . .	Chinese	120	...		
	Chen Tain . .	Chinese	7	...		
	Chek Yôk . .	Chinese	6	...		
Banhuni . .	Chek Hoe . .	Chinese	4	...		
	Chek Pein . .	Chinese	3	...		
	Chek Wan Chu .	Chinese	3	...		
	Nu Noi . . .	Siamese .	4	...		
		TOTAL .	225	...		

TABLE OF WEIGHTS.

English, Chinese, and Burmese.

Ton.	Bhara.	Pikul.	Pè.	Viss.	Catty.	lb.
1	5·6	16·8	102·3	613·7	1,680	2,240
	1	3	20·2	109·6	300	400
		1	6·09	36·5	100	133·3
			1	6	16·42	21·9
				1	2·73	3·65
					1	1·33
						1

MAUNG MAUNG,
District Surveyor, Mergui.

ERRATUM.

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA,

VOL. XXII, PART 3.

Page 172, line 2 from bottom, *for* 16·09 *read* 19·09.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1889. [November.

On the Land-Tortoises *of the* Siwaliks, *by* R. LYDEKKER, B.A.

In the Palæontologia Indica[1] I have described certain specimens which appear to indicate the former existence of several species of large land-tortoises in the Siwaliks, although I refrained, for several reasons, from assigning to any of them definite specific names. One of these reasons was the impossibility of determining to which genus they should be referred if the so-called *Manuria emys*, and therefore *Colossochelys atlas*, were regarded as generically distinct from *Testudo*. Since, however, Mr. G. A. Boulenger in his recently published Catalogue of Chelonians[2] has come to the conclusion that *Manuria* should be included in *Testudo*, there is no sufficient reason to justify the separation of *Colossochelys*, and accordingly one of the reasons against applying specific names to the other Siwalik forms likewise disappears.

The huge tortoise to which Falconer and Cautley applied the name *Colossochelys atlas* may accordingly be henceforth known as *Testudo atlas*. In the notice of this species published in the Palæontologia Indica (*loc. cit.*) the dimensions of the shell as restored by Falconer were accepted; the size being partially estimated on a restoration of the humerus. Subsequent observations show, however, that the restoration of that bone was much too long; and that the true length was nearer 20 inches than the 28 inches allowed by Falconer. Moreover, since that notice was written, the fragments of the carapace on which Falconer's restoration is based have been identified; and it appears from these that the restoration is likewise far too large, the interval between the nuchal bone and the inguinal patch being made nearly double its correct length.

Instead, therefore, of the carapace having a length exceeding eight feet in a straight line, a truer estimate would give this length as approximately six feet, or one-third greater than in the recent *Testudo elephantina*. These dimensions would, moreover, accord in relative proportions with the cranium described in the memoir cited, and provisionally referred (on account of its apparent relatively small size) to

[1] Ser. 10, vol. iii, pp. 157-170.

[2] London, 1889. Published by the British Museum.

a female individual, but which may perfectly well have belonged to a full-grown male. Unfortunately this specimen was not taken as the type of the species, and since there is a possibility that it may have belonged to the large Siwalik tortoise with less produced epiplastrals than *Testudo atlas*, its reference to the latter cannot be regarded as certain. It may, indeed, be observed in passing that it will be well to regard as the actual type of *Testudo atlas* the epiplastrals figured in plate xviii, fig. 1, of the memoir cited, since it is not absolutely certain that all the fragments on which Falconer's restoration is based are really referable to one and the same species. The nuchal bone so employed is characterized by the absence of a nuchal shield; but another large nuchal in the British Museum is characterized by the presence of a nuchal shield, and, therefore, indicates beyond doubt the occurrence of a second large Siwalik species of *Testudo*. If indeed the first-mentioned nuchal be rightly referred to *Testudo atlas*, the second one might well belong to the large tortoise with less produced epiplastrals, as typified by the specimen represented in plate xviii, fig. 4, of the memoir quoted. Since, however, I cannot assure myself that this nuchal may not have belonged to a large individual of the form mentioned below under the name of *T. cautleyi*, it is impossible to be absolutely certain that these epiplastrals do not belong to females of *Testudo atlas*, and I accordingly refrain from assigning a separate name to their owner, although there is great probability that this was really a distinct species.

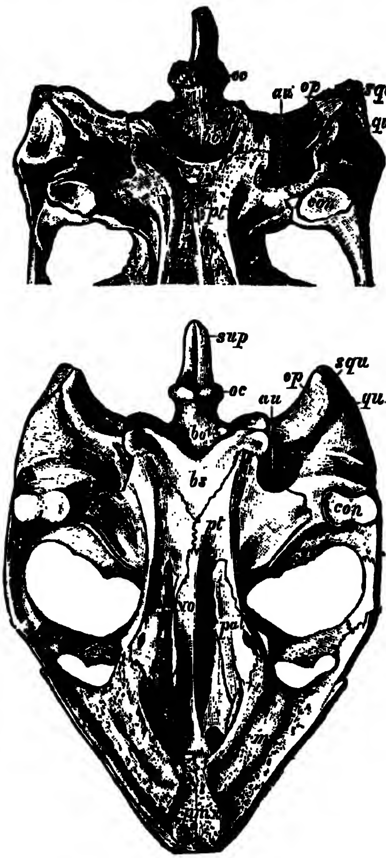


Fig. 1. Posterior part of the palate of *Testudo elephantina* (Aldabra); and palate of *T. microphyes* (Galapagos); both reduced. *au.* aperture of auditory labyrinth; *bo.* basioccipital; *bs.* basisphenoid; *con.* condyle of quadrate; *mx.* maxilla; *oc.* occipital condyle; *op.* opisthotic; *pal.* palatine; *pmx.* premaxilla; *pt.* pterygoid; *qu.* quadrate; *squ.* squamosal; *sup.* supraoccipital spine; *vo.* vomer.

In describing the above-mentioned cranium (*l. c.* pp. 161-162), it was stated that in the form of the palate it approximated to the giant tortoises of the Aldabra group. Further observations have, indeed, served to show that this resemblance is still more marked than was at first supposed. Thus, in the Aldabra tortoises (fig. 1 *A*), the aperture of the auditory labyrinth forms a wide and irregular opening, the opisthotics are not produced behind the occipital condyle, and the palate is deeply concave. In the Galapagos tortoises, on the other hand (fig. 1 *B*), the aperture of the labyrinth forms a narrow slit, the opisthotics

are produced considerably behind the occipital condyle, and the palate is much less concave. In the Mascarene tortoises, while the skull is on the whole nearest to the Galapagos type, yet the production of the opisthotics is much less marked. Now, the Siwalik cranium agrees with the Aldabra tortoises not only in the structure of the palate and the form of the aperture of the labyrinth, but apparently also (so far as can be determined) in the relative length of the opisthotics.

A totally different type of Siwalik tortoise is represented by an imperfect skull in the British Museum, of which the hinder part of the palate is shown in fig. 2. In this specimen, which indicates a somewhat smaller form than the preceding one, it will be seen from the figure that the form of the aperture of the labyrinth and the production of the opisthotics is precisely the same as in the Galapagos species. Since, however, I am unable to associate this type of cranium with any specimens of the anterior extremity of the plastron, I do not propose to give it any specific name. The two crania are, however, excessively interesting in showing the existence in the Indian Pliocene of two species of giant tortoises, one of which was allied in cranial characters to the tortoises of Aldabra, and the other to those of the Galapagos islands, and therefore also to those of the Mascarenes. That *T. atlas* and the above-mentioned unnamed tortoise were with shorter epiplastrals widely different in the characters of the shell from all the existing giant tortoises, is, however, shown by the great production of their epiplastrals; while in at least one of these forms the marginals of the carapace had their longer diameter at right angles to the periphery, as in *T. emys*, whereas in the modern giant tortoises the opposite condition obtains.

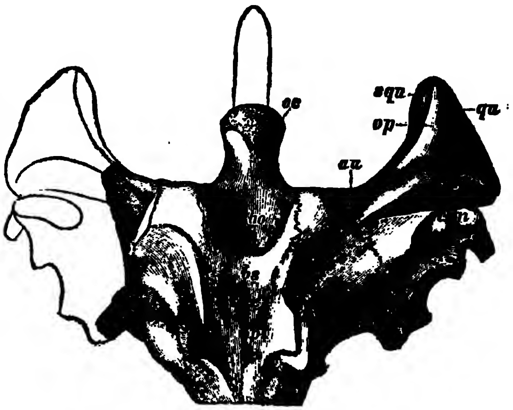


Fig. 2. Posterior portion of the palate of a large species of *Testudo* from the Siwalik Hills. 1½ nat. size. Letters as in fig. 1.

Leaving now the consideration of the crania and turning to the epiplastrals (which part of the skeleton it is advisable to take as the types of species in this Siwalik group), sufficient evidence is afforded for the foundation of two species in addition to *T. atlas*.

For the first of these species the name *T. cautleyi* may be adopted; and it is represented by the epiplastrals shown in fig. 3, *C*, which were obtained from the Siwalik hills, and are preserved in the British Museum. They indicate an adult tortoise of the approximate size of *T. elephantina*, and characterized by a similar slight production of the epiplastrals.

The second species, *T. punjabiensis*, is typified by the epiplastrals from the Punjab shown in fig. 3, *B*, which are described and figured in the Pal. Ind., ser. 10, vol. iii, p. 168, pt. xix, fig. 1. They indicate a species of somewhat smaller dimensions than *T. elephantina*, and are readily characterized by the epiplastrals

being produced after the manner of those of *T. emys* (fig. 3. *A*), although to a somewhat less extent. It is highly probable that the nuchal and xiphiplastral bones described on p. 169 of the memoir cited are likewise referable to this species; the nuchal has a large nuchal shield.

In conclusion, it may be observed that if we were beginning the description of the Siwalik tortoises with a free field, there would be no hesitation in taking the two skulls mentioned above as types of two distinct species, from both of which *T. cautleyi* would be sufficiently distinguished by its inferior size; but from this course we are now barred. The evidence which is gradually accumulating of the occurrence ot large tortoises during the later tertiary in many of the continental areas of the world (*e.g.* India, France, and South America), indicates that these forms were originally very widely spread, but appear to have been gradually driven off the continents, and have only survived to the present day in islands where they were free from the competition of higher types of life.

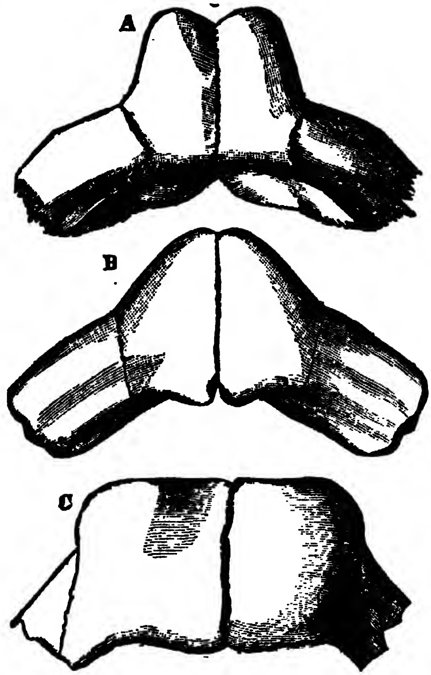


Fig. 3. Dorsal aspect of the epiplastrals of (*A* *Testudo emys* (recent); (*B*) *T. punjabiensis* (Siwaliks of Punjab); and (*C*) *T. cautleyi* (Siwalik Hills). Reduced.

Note *on the* Pelvis *of a* Ruminant *from the* Siwaliks *by* R. LYDEKKER, B.A.

In the year 1887 I gave a preliminary notice in the "Records"[1] of two bones from the Siwaliks, which were labelled by Falconer as being assoiated, and apparently referable to the same animal. One of these specimens is the imperfect tibio-tarsus of a bird, while I regarded the other as part of the sternum of the same bird; and on the evidence of these two specimens I proposed the name of *Megaloscelornis* for their presumed owner. Subsequently,[2] by making a section, I found that the tibio-tarsus could not be distinguished from that of *Struthio*, and I accordingly referred it to that genus, of which *Megaloscelornis* may accordingly be reckoned as a synonym.

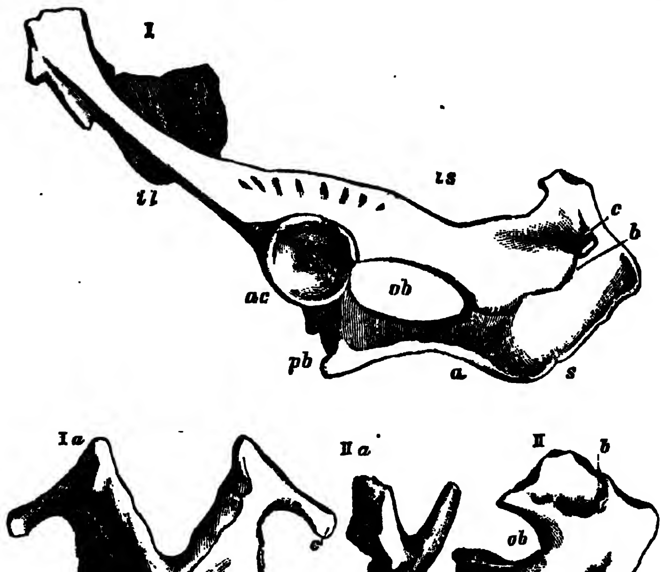
Having by this time acquired considerable doubt as to the real nature of the

[1] Vol. xii, p. 55.
[2] Pal. Ind., ser. x, Vol. iii, p. 143 (1884).

so-called sternum, I forwarded the specimen to Prof. Alfred Newton, of Cambridge, who, after examination, replied that, although it presented a certain superficial resemblance to an Avian sternum, yet he was convinced that it was not Avian at all, and he further suggested to me that it was really part of the shell of a Chelonian. This suggested re-determination was mentioned in the description of the tibia of *Struthio.*[1] At a still later date, however, after I made a considerable study of four Chelonia, I had occasion to enter this specimen (Ind. Mus. No. E. 6) in the Catalogue of Siwalik Vertebrata in the Indian Museum, pt. ii, p. 23 (1886), when I remarked as follows: "It has been suggested that the present specimen is part of the shell of a Chelonian, but the writer has been unable to satisfy himself that it is so."

Recently—in the course of cataloguing the fossil Chelonia in the British Museum—the question again arose whether this specimen (as represented by a cast) could be included in the list;—a question which I decided must be answered in the negative. It then occurred to me for the first time that the specimen might be a portion of a Mammalian pelvis, and after comparison with several groups (with the assistance of my friend Mr. O. Thomas, of the Museum) it was found to agree so closely with the hinder portion of the pelvis of the larger bovoid Artiodactyles that there could be no question but that the puzzle had been finally solved.

In the accompanying wood-cut figures are given of the left lateral (I) and posterior



Left lateral (I) and posterior (I*a*) aspects of the pelvis of *Oreas canna*; and the corresponding aspects (II, II*a*) of the fossil pelvis, ⅛ nat. size; *il.* ilium; *is.* ischium; *s.* symphysis of do.; *pb.* pubis; *ac.* acetabulum; *ob.* obturator foramen; *a.* epiphysis of ventral symphysis; *b.* muscular ridge; *c.* lateral process of ischial tuberosity.

[1] Pal. Ind., *loc. cit.*

(I*a*) aspects of the pelvis of the Eland (*Oreas*), and also of the corresponding aspects (II, II*a*) of the specimen under consideration. It will be seen from these figures that the fossil comprises the posterior portion of the ischia of an animal of rather larger dimensions than that to which the recent pelvis belonged. Below the obturator foramen (*ob.*) the ischia are broken off at their junction with the pubes; while above this foramen they have lost the anterior portion of the bar which enters into the formation of the acetabulum (*ac.*), and posteriorly the whole of the region embracing the tuberosity and its lateral process (*c*). The strongly-marked ridge for muscular attachment situated posteriorly to the obturator foramen is, however, well preserved. Posteriorly (II*a*), one side of the bar bounding the outlet of the pelvis has been fractured and somewhat displaced, so as to render this aspect of the specimen somewhat unsymmetrical.

In all respects the fossil fragment agrees so closely with the corresponding portion of the figured pelvis as to indicate that it certainly belonged to one of the larger *Bovidæ*, the most characteristic features being the elongated form of the obturator foramen (*ob.*), the contour of the muscular crest (*b*), and the great development and convexity of the epiphysis (*a*) on the ventral aspect of the symphysis. The specimen, indeed, comes nearer to the pelvis of the larger antelopes than to that of the oxen; and it is probable that it belonged to one of the large Siwalik antelopes which are allied to existing African forms. The muscular ridge (*b*) is, indeed, placed higher relatively to the obturator foramen than in the eland or any antelope with which I have been able to compare the specimen; but this is not a character of much importance.

In finally referring this specimen to its true position, I may again repeat the warning it gives against attaching any importance whatever to the association of Siwalik specimens.

Recent Assays *from the* Sambhar Salt Lake *in* Rajputana, *by* H. WARTH, PH.D.

In his paper on salt in Rajputana (Records, 1880, page 197), Mr. C. A. Hacket referred to the apparently unfailing supply of salt in this lake. It is now twenty years since the lake was taken over by the Salt Revenue Department under the Government of India; and from the year 1869 to 1888 no less than 52,400,000 maunds of salt were extracted and removed, which is equal to about two million tons. Mr. Hacket quoted in his paper the analysis which I made at the lake in 1869 with somewhat primitive appliances. The water in the lake (lake brine A) contained 21·9 % dry residue, which was composed as follows:—

Sodium chloride	90·9
„ sulphate	7·3
Balance, chiefly sodium carbonate	1·8

Unless the lake would be inexhaustible, the removal of two million tons of salt (sodium chloride) must produce a change in the composition of the soluble residue. I have

now made a careful analysis of the residue of lake brine drawn in January 1889, and the result is as follows. There are 8·81 % of residue, and the composition is—

Sodium chloride	87·6
„ sulphate	7·5
„ carbonate	4·6
Balance	0·3

Only in the latter analysis was the carbon dioxide directly determined, therefore it is not safe to draw conclusions from the large increase of sodium carbonate, but the sulphate is also increased.

Calculation based upon the proportion of sulphate to chloride in both cases shows the lake ought to last another three hundred years at the past rate of consumption. On the other hand, the actual decrease in the percentage of chloride would predict an end of the salt stores in sixty-five years. It is desirable that analysis should be repeated in the following years, and for this purpose the samples of brine should be taken when the lake is not concentrated, so that natural separation of common salt at the edges of the lake causes no relative increase of foreign salts. Percolation brine is obtained all over the lake-bed by excavation. It contains more foreign salt than the brine of the lake itself. I analysed a sample which was obtained by mixing percolation brine from all along the sixty miles of lake edge.[1] This sample compares as follows with percolation brine (or subterranean brine C) of 1869:—

	Percolation brine. 1869.	Percolation brine. 1888.
Dry residue	20·1 %	12·3 %
Sodium chloride	86·1	85·3
„ sulphate	12·4	11·3
„ carbonate	1·5	3·0
Balance		0·4

An isolated sample of percolation brine obtained in 1888 was exceptionally pure: its residue contained only 6·9 % sodium sulphate. This proves that the percolation brine varies much in composition.

I also analysed some extract salt prepared out of residual liquor (mother liquor) from the salt manufacture. The result was—

Sodium chloride	62·0
„ sulphate	18·0
„ carbonate	17·7
Balance	2·3
	100·0

Dr. Bauer, of the Chemical Laboratory, Stuttgart, suggested my trying for boracic acid, and when I did so, I was surprised to find that the above balance consisted to a large extent of borate of sodium (borax). Subsequently I observed that the ordinary brine of the lake showed the reaction for boracic acid also, and by a rough method I proved a yield of something like a half per cent. of crystallised borax in the dry residue of the lake brine.

[1] I am obliged for this and other specimens to Mr. Carey, C. S., the Commissioner of the Northern India Salt Revenue Department.

During an annual production of 30 lakh maunds of salt at the lake, the waste liquor, which is thrown away, contains therefore boracic acid enough to yield 15,000 maunds of crystallised borax, or in round numbers 500 tons. One ton of refined borax costs in Europe about R1,000.

Considering also the value of the soda in the waste liquors and even of the sulphate, it ought some day to be possible to combine the separation of borax and other sodium salts with the production of the pure edible salt.

The 3rd August 1889.

The Manganiferous Iron *and* Manganese Ores *of* Jabalpur, *by* PRAMATHA NATH BOSE, B.SC., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With one plate.)

In Vol. XXI, No. 3, of the "Records," I gave a sketch of the economic results of the manganese exploration in the Jabalpur district. In the present paper I propose giving, first, a geological sketch of the ground in which the manganese iron and manganese ores occur, and then, a summary of the observations which I made on their origin. (For map see Rec., Vol. XXI, Pt. 4.)

I.—GEOLOGICAL SKETCH.

1. The Bijawars.

Division into groups.

Mr. C. A. Hacket, who surveyed and reported upon the area under description in 1871, divides this series into four groups as follows (in descending order) :—

1. Chanderdip group.
2. Lora ,,
3. Bhitri ,,
4. Majhauli ,,

Mr. Hacket observes that the boundaries between these groups are "by no means well defined, as they pass almost imperceptibly into each other," and that this division is made for "convenience of description."[1]

The Chanderdip group is not exposed in the manganese ground; and for our purpose it would be more convenient to unite the Majhauli and Bhitri groups under one denomination. We have thus to deal with two groups, which are (in ascending order)—(i) the Majhauli-Bhitri and (ii) the Lora.

Majhauli-Bhitri group.

This group consists of limestones, shales, and green-stone like rocks. They stretch in a north-east—south-west direction (the direction of the strike) from Sleemanabad and Salaia to Majhauli and Indrana. They also occur in the southern portion of the area near Chhatarpur.

[1] MS. Report, p. 3.

Limestones, cherts, and quartz rocks.

The limestones or dolomites are generally cherty, often chert-banded. The dip as indicated by this banding is usually very high, sometimes approaching verticality. The limestone is never continuous over any considerable area; indeed, it is seldom traceable for more than 4 or 5 miles along, or a mile across, the strike; often it forms inconsiderable patches, only a few square yards in extent. It is associated more or less obscurely with quartzite and quartzose rocks of various kinds, the commonest being a hard cherty rock (with nests and strings of white quartz), generally tinged red or yellow. The quartz nests give the rock a brecciated appearance, which is also emphasized at places by the presence of fragments of quartzite. The cherty rocks occur in huge, shapeless masses, without a trace of bedding, and look like fault rock. But no indication of faulting was observable anywhere. At places—as, for instance, west of Majhauli and in the vicinity of Chhatarpur—the cherty rocks are so intimately associated with the limestones that it is almost impossible to separate them on the map. In fact, they here represent what in other parts of the district is essentially a limestone group.

These cherty beds form ridges which run with the general Bijawar strike. One such ridge runs almost uninterruptedly for 10 miles from Salaia (3 miles south of Sleemanabad) to Gouruha Bhitoli. The limestone outcrops invariably occur on comparatively low ground and usually at the foot of these ridges.

Jaspery bands.

Banded red jasper was met with, associated, like the cherty quartzites, with the limestones at diverse localities. The bands dip in the same manner as the chert bands do in the limestones that are chert-banded. When the two (the banded red jasper and the chert-banded limestones) are in close proximity, as they are at Salaia, the one passes almost imperceptibly into the other.

The cherty and jaspery rocks are often found in intimate association with that puzzle of Indian geology, "Laterite," as in the neighbourhood of Chhapra (Bara, 3 miles south of Sleemanabad) and elsewhere.

Shales were found interbedded with the limestones at various places. At Gouruha the latter are replaced by the former laterally in a rather abrupt manner. The shales are distinctly bedded dipping 70° south-east, and are contorted at places. They form a nearly continuous band, extending as far as Ponri (5 miles south-west of Gouruha), beyond which they are lost under alluvium. Red slaty shales with chert bands are very largely developed about Majhauli.

The limestones were observed to be cleaved at places; but their cleavage is not apparent except on the weathered surface, which also sometimes shows crumpling.

A band of a peculiar-looking green-stone like rock runs from Dhinari Khamarea (4 miles north of Sihora) in a north-eastern direction (the direction of the strike) to Dhangaon, a village situated on the Mirzapur road, 7 miles north of Sihora. The rock also occurs north-east of this village. Here, as well as at Dhinari Khamarea, it appeared to pass into the shales; but the passage was not distinctly seen.

The Lora group.

There are two important outcrops of the Lora group within the area explored last season. One of these extends from the north-eastern extremity of the Lora range east of Sihora to Murhasan and Chindamani, 6 miles south-west of Gosalpur, and includes the towns of Sihora and

Gosalpur. The other occurs east of Panagar and extends north-eastward through Chhatarpur and Agaria to Saroli. The connection between these two outcrops is not clear, as the intermediate ground is mostly obscured by alluvium. There is, I am strongly inclined to think, some faulting.

The first of these two outcrops, which may be called the Sihora-Gosalpur out-crop consists of a lenticular patch of shales and thin,—frequently micaceous,—hematite-banded quartzites, flanked as it were by massive quartzites not very unlike those described as occurring in the preceding group. The shales and micaceous hematite-banded quartzites form a distinct synclinal (which we shall call the Lora syncline) just west of Gosalpur, their dip at Gosalpur pointing north-north-west and at Ghugri in the opposite direction. In the south-western direction the syncline is traceable to Murhasan and Khorawul, the micaceous,—hematite-banded quartzites, or hematite quartzites, as they may be more conveniently called, forming two broken parallel ridges, and the shales superposed on them, the valley between. North of Gosalpur, the syncline is more or less distinctly traceable to the Lora range proper, where the rocks are greatly folded and contorted.

The hematitic quartzites and associated rocks may for the sake of convenience be called the Sihora beds, after Sihora, the only place of importance in the neighbourhood of the Lora range where they are typically developed; and the massive quartzites which have been mentioned above as nearly enclosing or flanking these beds may be named after Gosalpur, where they are fairly well seen, as Gosalpur quartzites.

The relation of the Sihora beds to the Gosalpur quartzites is generally very obscure, owing to the usual absence of dip-indications in the latter. The dip is, however, seen at places, as in the Mansukra-Silondi ridge close to Sihora, and at Pahrewa, 2 miles south of that town. From these dips, as well as from their mode of occurrence, the Gosalpur quartzites would appear to underlie the hematitic quartzites and associated rocks (the Sihora beds), and form the base of the Lora group.

There is considerable lithological similarity between these quartzites and the cherty and jaspery rocks of the Majhauli-Bhitri group. Hand specimens of the one would be almost undistinguishable from those of the other. But, except at one place,[1] they have nowhere been found associated with limestones. They are variously coloured,—white, blue, red, brown, and yellow, the blue colour indicating the presence of manganese ore. At places they have an appearance of brecciation, which is sometimes very coarse, owing to the presence of veins and nests of manganese or iron ores. As the pyrolusite occurs almost exclusively in the Gosalpur quartzites, it would, from an economic point of view, be important to describe its outcrops in some detail. It is possible that future search at places where no ore, or only traces of it, have been found by me will prove more successful.

About Khorawul, at the south-eastern extremity of the western side of the Lora syncline, there is an immense development of quartzites. They do not all appear to belong to the same horizon. The Sihora strata are present at Khorawul in a greatly attenuated condition, and the quartzites apparently underlie as well as overlie them. It is more than possible that they in part replace the Sihora strata.

[1] Near Karaia, south of Kaleri (Kulery).

But the stratigraphy here is very obscure. East of Khorawul, and separated from the quartzites just mentioned by a short interspace of alluvium, there is another patch of massive quartzites at Keilwas. Just north of this village these quartzites are overlaid by a thin band of micaceous,—hematite-banded quartzites, superposed by shales.

Further north from Chandnota and Dharampur, the Gosalpur quartzites are traceable, though more or less covered by alluvium, at the base of the Sihora strata (which form a ridge running north-east along the strike) to Naigain, thickening and thinning out at places. North of Naigain, the quartzites, as well as the superjacent Sihora strata, are concealed by alluvium. There is either some faulting here or a twist of the strike.

Proceeding northward on the same (the western) side of the Lora syncline, the quartzites re-appear in great force at Sihora. They are here greatly mixed up with laterite. North-east of the town, they form a ridge running with the strike, nearly as far as Murhie. They again appear south of Karaia (not marked on map) near Kaleri (Kulery), and run through Daimapur to Tola, beyond which they are covered up by alluvium. There are quartzites of a similar aspect at Umaria. They are probably identical. If so, a considerable twist in the strike must be supposed to have taken place in the intermediate ground.

A mile north of Sihora, and separated from the quartzites occurring there by an interspace of alluvium, there are at Raipur (Reipur) quartzites of a similar appearance, but more intimately associated with laterite. They run through Chhapra (Chhota) to Karaia, where they appear to unite with the quartzite band described above.

On the eastern side of the Lora syncline, at its southern extremity, there is an insignificant outcrop of the Gosalpur quartzites at Murhasan. Traced northward, they are lost in lateritic-looking rocks which form a nearly continuous ridge as far as Gosalpur. Within this lateritic ground, however, a few blocks of quartzites were found at Deonagar near Burhagar.

The quartzites re-appear at Gosalpur just west of the dâk bungalow. They are surrounded by laterite on all sides. Just north of the village, by the Mirzapur road, mottled quartzose rocks appear in an old well and in some pits excavated close to it. These rocks probably represent the Gosalpur quartzites. Further north, a well-defined ridge of laterite runs from Jujhari (Joojharee) to Bandha. Within this lateritic ground, however, small fragmentary patches of massive unbedded quartzites occur, as close to the village of Bandha. North of Bandha all is alluvium as far as Khatola and Bhatadon, with the exception of a very small piece of ground just south of Rethowri, where quartzites in close association with laterite were encountered.

There is a good show of the quartzites at Khatola (E. I. Railway Station), where they are worked for railway ballast. Hence they run on through Hargar, Danwie and Mungala to Deori, at places concealed under alluvium or getting lost in laterite. Beyond Deori the laterite predominates. A few fragmentary patches of quartzites, however, were met with at Dharaisar and elsewhere. If the Dharaisar quartzites be identical with Gosalpur quartzites, there is a remarkable twist of the strike here corresponding to a similar twist mentioned above as occurring on the western side of the Lora syncline at Umaria (Oomuria).

A minor band of quartzites is obscurely traceable from a short distance south of Burhagar, through Keolari (a deserted village a mile south of Gosalpur) to Budhua (Boodooa). Its course is roughly parallel to that of the quartzites running through Gosalpur. If the Burhagar and Keolari quartzites be identical with these, as I am inclined to think they are, they have been brought into the position they occupy by a minor anticlinal flexure. There is evidence, though very obscure, of considerable disturbance in the entire Lora group at, and east of Gosalpur.

In the Lora outcrop east of Panagar the Gosalpur quartzites were well seen at Nurgaon, 4 miles north-east of Panagar, distinctly bedded, and passing with a south-eastern dip under shales and micaceous,—hematite-banded (or hematite) quartzites (the Sihora beds). The Gosalpur quartzites here form a ridge extending for about 2 miles north-eastward along the strike. At Agaria, 5 miles further north in the same direction, some quartzites were met with which probably belong to the same horizon.

Two miles south-east of Panagar, there is a strong band of apparently much-crushed Gosalpur quartzites which runs very nearly in an east—west direction parallel to the Lamehra range of hills.

The sequence of the Sihora beds is as follows (in ascending order):—

1. Slaty shales.
2. Thin laminated quartzites usually of a jaspery type, and often parted by layers of micaceous iron ore interstratified with shales.
3. Slaty shales, usually sheeny and tinted red.

This sequence is typically developed at Ghugri (west of Gosalpur) and a few other places; it is not observable everywhere. The beds (2) are best developed in the Lora range east of Sihora, and are the most striking in the entire Lora group. The micaceous iron layers, which are usually of very small thickness (less than a quarter of an inch or so), are sometimes entirely wanting, as at Murhasan; sometimes they are developed to such an extent that the rock may be called a micaceous hematite schist, which is the case at Dharampur, Gosalpur, &c.; and sometimes the quartzites pass laterally into shales, as north of Gosalpur. This lithological variability is highly characteristic of the Gosalpur quartzites also.

All the beds of the series, especially those just described, show signs of great disturbance. The dip is high—nowhere less than 45°. The beds are folded and crumpled. The folding is sometimes very sharp and is well seen throughout the Lora range. Cleavage was distinctly observed in the shaly strata at some places, the dip of cleavage planes being in the same direction as that of the bedding planes, but higher.

The course of the Sihora strata being roughly parallel to that of the Gosalpur quartzites, it need not be traced in detail.

2. *The Lateritic rocks.*

The mapping of these rocks has been a source of great anxiety to me. In the area examined last season they may be classed as follows:—

First.—Lateritised Bijawar rocks,—*i.e.* rocks which by the action of percolating water charged with iron manganese, &c., have been altered, and come to

assume an unbedded, massive, more or less cellular form. Such rocks occur just in front of the dâk bungalow at Gosalpur. Here the passage from micaceous iron slates, belonging undoubtedly to the Bijawar formation, to lateritic rocks without a trace of the slates left in them, is clear and gradual. Similarly lateritised ferruginous slates were met with at Keolari, Burhagar, Hirdenagar, &c., within the ground previously mapped as Laterite. All such ground has now been reclaimed from it, and coloured as Bijawar.

Secondly.—Lateritic rocks which have been mentioned before in connection with the Gosalpur quartzites, and the relation of which to these as well as to the other rocks of thė Lora group is extremely obscure. They are well seen in the ridge just west of the dâk bungalow at Gosalpur. The ridge slopes gently eastward,—*i.e.* towards the bungalow,—and is scarped on the western side, the scarp being somewhat steep. On this, the western side, the Sihora strata crop out, rolling about considerably, but usually dipping rather high in a north-western direction. The lateritic rocks come in towards the summit of the ridge, looking as if they capped the Sihora strata. But at the junction at one place where the latter appeared to be overlaid by the former, a shaft was sunk to a depth of 25 feet; and the entire thickness was found to consist of the lateritic rocks—white, yellow, and red mottled, gritty, ferruginous clays, apparently without a trace of stratification. These rocks become more and more vesicular above; and at the summit of the ridge, they are full of irregular vermicular tubes formed evidently by percolating water. Their disintegration results in a large spread of gravel, which is found along the slope of the ridge mentioned above, as well as in the ground to the south of the dâk bungalow. The gravel, which looks much more highly ferruginous than the parent rock, is re-cemented at places by a ferruginous matrix, producing lateritic alluvium, which will be mentioned presently.

The relation of the lateritic rocks under discussion to the Gosalpur quartzites is very peculiar. The former curiously follow the course of the latter and *alternate* with them. The quartzite outcrops, however, are frequently few and far between, and quite insignificant,—sometimes not more than a few square yards in extent. In several pits, as at Keolari, large blocks of the quartzite were found *in situ* surrounded by laterite on all sides. They are highly ferruginous and much decomposed at the edges. It did not appear to me quite beyond the range of possibility that the lateritic rocks here might be the result of the decomposition and alteration of the quartzites, as the laterite in front of the Gosalpur dâk bungalow is the result of the alteration of the Sihora ferruginous slates *in situ.* The laterite overlying the quartzites at Gosalpur appeared to me to be possibly of a similar origin. This impression was created by the manner in which, in the numerous pits opened there, the decomposed yellowish and yellowish-white quartz rock with veins and nests of manganese or iron ore, or both, occurring at the bottom, gradually passed upward, first into a layer containing fragments of the quartzite and of the ore-bearing blocks with the quartzite matrix occupying drusy cavities, and then into a layer of grains and nodules of the ore, in which the original rock-matrix is barely discernible at places. Pumpelly expresses a similar view with regard to the origin of the manganese ores of Missouri and Michigan. They occur in a "black porphyry with very hard matrix,

abounding in grains of smoky quartz and crystals of triclinic felspar." They are "in narrow comby strings, which are in places isolated, in others united to form a reticulated net-work throughout the mass; in this form the rock resembles a conglomerate, the ore representing the cement." [This is exactly the manner in which the pyrolusite occurs in the Gosalpur quartzites.] "In other instances the manganese has wholly replaced the matrix, the crystals of felspar and grains of quartz alone remaining intact. Finally, in portions of the rock, the replacement has been complete; here no traces of the porphyry, either crystals or matrix, remain, while a more or less porous semi-crystalline mass of the manganese ore takes their place." ["Iron Ores of Missouri and Michigan," Part I, p. 25.] The "manganese laterite", into which the pyrolusite-bearing quartzites of the Jabalpur area pass above, resembles this porous semi-crystalline mass. The nodules towards the surface are usually of a spongy texture; and this texture is more satisfactorily explained by regarding the cavernous spaces to have been originally occupied by the quartzose matrix as in the layer immediately underlying them, than on any other hypothesis. But even if the mode of origin here suggested be correct, it would possibly account for only a very small portion of the lateritic rocks. Over the great spread of these rocks south-west of the Gosalpur dâk bungalow, no such connection between them and the quartzites is discernible in the numerous pits opened in them. It is not impossible that they may represent the Gosalpur quartzites, the lithologic change from mottled gritty clays to quartzites not being inconceivable; and the manner in which the two kinds of rocks run into each other gives colour to such a supposition This is, however, only a possible view, and nothing more. On the view of the lateritic rocks having been deposited on the Gosalpur quartzites in comparatively recent times, from the manner in which the latter crop out they must be supposed to have undergone considerable subaërial denudation, and then to have been depressed before the former were deposited. The adjoining Sihora shales, which now form the long and well-defined valley west of Gosalpur, must have been denuded and depressed at the same time. It is noticeable, however, that the lateritic or any corresponding rocks are entirely absent from this valley, as also from a similar valley south of Sihora formed by the denudation of the same shales.

Thirdly.—Lateritic alluvium.—It is distinctly of detrital origin. It graduates into ordinary alluvial clay or loam with pisolitic or oolitic concretions of iron or manganese ore.

II.—ORIGIN OF THE MANGANIFEROUS IRON AND MANGANESE ORES.

Source of the ores.

The manganese ores of Jabalpur occur in the transition formation, and chiefly in the Lora group. In other parts of India, Mr. Ball notes the occurrence of manganiferous ores mixed with vein quartz, south of Chaibassa, in the same formation; and Mr. Hacket found them at the base of the Arvali series in Bundi (Rajputana).[2]

There can be hardly any doubt that the original source of the manganese ores of the Jabalpur ground is to be sought for in the micaceous,—iron-banded quartzites

[1] Memoirs, G. S. I., Vol. XVIII, pt. II, p. 86.
[2] Records, G. S. I., Vol. X, p. 91.

of the Lora group. The hematite usually assumes the form of micaceous iron ore, and has manganese disseminated in it, though in very minute quantities. The manner in which the hematite layers follow the complicated flexures of the accompanying quartzites leaves little room for doubt that they are true beds contemporaneous with the latter. At places the hematite predominates, and the quartzite is quite subordinate or entirely wanting. If this latter condition be due to original deposition, it is conceivable that at these places the same forces which produced the folding and crumpling of the hard quartzites would result in the cleavage of the comparatively soft micaceous iron-ore strata; and that mineral re-arrangement along cleavage planes might produce a schistose hematite such as was exposed in the trenches at Gosalpur and elsewhere.

The manganiferous hematite.

The manganiferous hematite is to be distinguished from the micaceous iron ore just mentioned by the fact that manganese is present in some quantity in the former and makes itself apparent in the form of veins and nests of *psilomelane*. Two kinds of the manganiferous hematite may be distinguished according to their origin: one produced by the local concentration of the manganese in the micaceous hematite, and the other by the impregnation of the shales and quartzites acccompanying this hematite. Rich pocket-like deposits of manganiferous hematite have been produced in either of these ways. They are invariably richest towards the surface; beds which are but slightly impregnated with the manganese iron ores in the form of veins and nests, becoming at or near the outcrop so rich as to claim to be called ore beds. The manganese iron ore beds of the Mansukra Silondi ridge near Sihora are beds of this description.[1]

Manganese in the manganiferous hematite.

The manganese in the manganiferous hematite, whether formed by the concentration of the manganese in the micaceous hematites or by the impregnation of other Sihora strata, is met rather in the form of veins and nests of psilomelane. These veins and nests increase in number and magnitude towards the surface, nearly pure masses of the mineral, with but a slight admixture of hematite, being thus produced at the surface.

Manganese deposits precipitated at the surface.

Sometimes there occur surface deposits of psilomelane which cover the underlying strata in such a manner as to leave but little room for doubt that they are not the result of impregnation or concentration. The usual mode of occurrence of such deposits is represented in fig. 2. It is possible to conceive that the ore-mass *c* has been formed by the replacement-alteration of the fragments of micaceous hematite schist visible in *b*. But there is no passage from the one to the other; and not unfrequently the ore-mass *c* covers the edges of the micaceous hematite schist *a* without the intervention of the ore-mass *b*. Under the circumstances the most eligible supposition appears to me to be that the ore-mass *c* has been precipitated from water above the outcrop of the strata *b*.

Manganese deposits the result of impregnation accompanied by replacement.

From the manner in which the manganese deposits occur at places,—as, for instance, the pyrolusite deposits at Gosalpur,—they appear as if they were formed by impregnation accompanied by replacement of the rock by ore. In the numerous pits which were sunk into the manganese deposits at Gosalpur and

[1] See Records, Vol. XXI, p. 85.

elsewhere, the rock at the bottom is decomposed, and has frequently a blotched appearance owing to the presence of specks and patches of what appears to be some form of manganese or iron ore. These ore particles are seen under the microscope not only to occupy the interstices between quartz grains, but also to invade and gradually replace these. A slice of the Gosalpur quartzite from Pahrewa containing veins and nests of manganese ore from a portion of the rock in which the ore was not discernible macroscopically, showed an abundance of curious needle-like brownish microlites (?), along with a few black patches evidently of manganese ore (see plate). The needles are so numerous that they form a felt-like mass, through which the quartzose rock matrix is discernible only with polarized light.

Overlying the blotched decomposed quartzite mentioned above, we have, proceeding upward, first, the decomposed quartzite traversed by a net-work of veins and nests of manganese or iron ores; then blocks and fragments of the quartzite, some of which are very rich in the ores; in which case the quartzite, much decomposed and crumbly, has the appearance of occupying cavities in the ore-mass; and, lastly, grains and nodules of the ores without any admixture of the rock. (See plate, fig. 1.) This mode of occurrence of the ores and certain features which they present—their spongy texture, for instance — I could not satisfactorily account for without supposing the replacement of the rock by the ore to a certain extent. The loose, crumbly, decomposed rock accompanying the ore being washed or dissolved away, its place may be gradually taken by the manganese iron ores either occurring along with the rock or freshly precipitated from percolating water. It is possibly owing to this sort of displacement of the rock by the ore that the loose ore-nodules covering hill slopes are, as a rule, much richer than the ore *in situ* from which they appear to have been derived — a fact which has been noticed before.[1] It is not unlikely, however, that they may be the remains of a rich surface-deposit of ores which has been denuded away.

Replacement of rock by ore to a subordinate extent.

However, the displacement of the rock by ore accounts for the origin of the ore-deposits only partially, and possibly to a subordinate extent. They must have been mainly formed by precipitation from percolating water in cracks and crevices of the rocks. These cracks and crevices would be largest and most abundant at the outcrops (where the rocks are broken up into blocks and fragments), and would diminish in number and magnitude with depth. We would thus have the ore-deposit richest at the crop; and the rock here would frequently present the appearance of a 'crushed' breccia or conglomerate, cemented, as it were, by the manganese iron ores, as it does at Gosalpur, Dharampur, and other places. (See fig. 2 *b*.)

Managanese brought up by ascending springs.

The hypothesis of springs bringing up manganese in solution from the underlying strata may account for the formation of certain superficial ore-deposits,—as, for instance, the deposit *c* in fig. 2. The ascending waters on coming to the surface would deposit the manganese as oxide, the conditions for the escape of carbonic acid, and for the

[1] Dr. King noticed near Vizianagram, at the foot of a hill, large blocks and smaller masses of manganese ore which appeared to have rolled down from above. The ore *in situ*, however, occurs higher up the slope, as a thin and irregular coating of limestones (Records, Vol. XIX, p 155).

cooling and evaporation of water being very favourable here. The manner in which the Lora beds have been folded and crumpled plainly shows that they have suffered exceptional disturbance, which, in all probability, was accompanied by considerable fissuring; and this condition must have been favourable to the production of numerous springs.[1] The concentration of manganese in the micaceous hematite schist, and the impregnation of the associated strata, as well as of the Gosalpur quartzites, may also have been effected by the ascending waters of springs. Precipitation of manganese as oxide from such waters would be most effective at, or close to, the surface, owing, in the first place, to the atmospheric condition being most favourable for it there; and, in the second place, to the rocks there being much fissured by weathering action. Thus we should have the ore-deposits richest at the surface—which is actually the case.

Manganese deposits precipitated from surface waters.

The ore-impregnations may, however, be generally accounted for quite as satisfactorily on the supposition that they have been precipitated from infiltrating surface-waters which have leached out the manganese and iron from the hematite-banded quartzites or from the micaceous hematite schists. This is the view entertained by Mr. Mallet.[2] As facts favourable to it, I may mention that I saw the plaster-coating of a *baoli* at the foot of the Lora hill was encrusted over by manganese ore, which there can be hardly any doubt was derived from the manganiferous strata forming that hill; and that the soil at the foot of some hills containing manganese ores was found to be similarly coated by manganese, as at Ponri. Bischof mentions a case in which peroxide of manganese was found to be present in a deposit from mine-water which was still being formed.[3]

There can be hardly any doubt that manganese iron deposits are being formed at the present day by precipitation from surface-waters which have leached out the manganese and iron from the micaceous hematite of the Sihora strata; and similar deposits must have been forming ever since the elevation of the Bijawurs. Whether all of the deposits which we see at the present day have been formed in this way, it is difficult to say. It is possible that some of them, like the psilomelane deposits covering the edges of the Sihora strata at the outcrop, owe their origin to deep-seated springs. But as we have no certain evidence of the existence of such springs, it would, I think, be safest not to assume it, but account for all of the deposits by means of agencies which we see at work at the present day, if they can be so accounted for, and there does not appear to be any insuperable difficulty in the way of so explaining them.

At some places, as near Sihora and at Pararia (near Panagar), we have the ridges formed by the Gosalpur quartzites containing manganese ores at some distance from the ridges formed by the Sihora beds with interstratified micaceous hematite (which

[1] The manner of occurrence of the manganese deposits in the Department of Hautes Pyrenées, which is similar to that of the Jabalpur deposits, appears, according to Gruner (quoted by Bernhard von Cotta in his "Treatise on Ore Deposits") to indicate that the ores have been deposited by mineral springs, containing bicarbonate of manganese in solution, which have penetrated to the surface.

[2] Records, Vol. XVI, p. 117.

[3] Bischof's "Chemical and Physical Geology," Vol. I, p. 161. (Translation, London 1859.)

has been assumed t be the source of the manganese ores), and separated by an interspace of alluvium or of rocks from which the ores are absent, except as mere traces. In these cases the manganese deposits must have been formed before the carving out of the valley between them and the ridges containing micaceous hematite.

Capillarity.

In some cases boulder-like masses of the Gosalpur quartzites were observed to be coated with manganese ores at some height above the surface of the ground. The encrustation could not clearly have been effected by percolating waters in the same way as the coating of the soil or of masonry structures referred to above. It is possible to suppose that the quartzites in question had been impregnated with ore before denudation brought down the surface of the ground to its present level,—that is to say, while the manganese-charged waters flowed over the surface of the quartzites. But while I can find no serious objection to such a supposition, some observations which I made led me to think that the quartzites may have been impregnated with ore in the position they occupy at present. At the foot of a hill at Ponri (wherein manganese ores occur), I observed the mud walls of a dilapidated hut some twenty years old to be coated with manganese, half a foot above the surface of the ground. There was no indication here of the lowering of the surface. In this case, and in that of the manganese-coated upstanding masses of quartzites, the manganese-charged surface-waters appear to me to have risen up the quartzites and the mud walls owing to capillarity; and the manganese has then been precipitated much in the same way as it has been thrown down on the soil, and in the cracks and crevices of rocks.

EXPLANATION.

Fig. 1.—Section in Pit XXXI, Gosalpur—

a. Blocks of pyrolusite, with a little quartzite,
*a*¹. Nodules of pyrolusite.
b. Ditto iron-ore.
c. Blocks of quartzite, with a little manganese ore.

Fig. 2.—

a. Micaceous hematite schist (manganiferous).
b. Psilomelane, with bits of the schist.
c. Psilomelane.

Fig. 3.—Slice of quartzite, impregnated with manganese ore. Pahrewa, near Sihora.

On some Palagonite-bearing traps *of the* Rájmahál hills, *and* Deccan, *by* C.S. MIDDLEMISS, B.A., *Deputy Superintendent, Geological Survey of India.* (With three plates.)

General McMahon, in describing some Rájmahál and Deccan traps (Records, G. S. I., Vol. XX, page 104), mentions a peculiar substance which appears sometimes

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Fig. 1

Fig. 2.

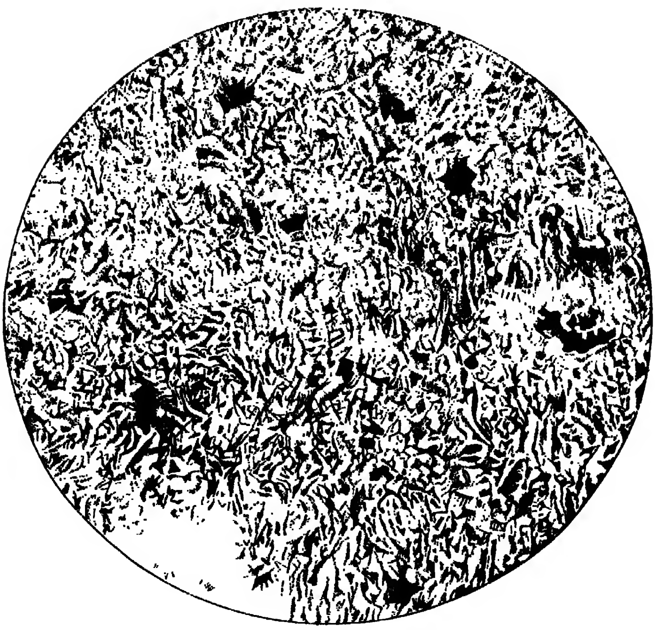

Fig. 3.

to fill up amygdules as a zeolite, and sometimes to play the part of a glassy base, in as much as it is perfectly isotrope under the microscope, with crossed nicols, and resists boiling with mineral acids.

With reference to specimen No. $\frac{1}{421}$ (these and other similar numbers being those of the rock-register of the Geological Survey Museum), he writes—

"A zeolite, varying from white to yellowish-red in colour, stops the amygdules, and invades the substance of the rock, forming very numerous *lacunæ*, with strongly marked marginal borders. The inner portions of many of the large felspars have also been replaced by this product of decomposition."

Of specimen No. $\frac{1}{438}$ he writes—

"The products of decomposition are in No. $\frac{1}{438}$ a greenish-brown; and in No. $\frac{1}{440}$, a substance that is of greenish-brown colour in some places, and yellowish-red in others. This cannot be traced directly, or indirectly, to the al teration of the augite; on the contrary it fills the rôle of a glassy base, and possibly represents the uncrystalized residunm . . . . . . Occasionally in No. $\frac{1}{438}$ the greenish-brown matter appears in rounded forms, suggestive at first sight of pseudomorphs after olivine, but this appearance is, I think, delusive; and the hypothesis that might be based on it is refuted by the general behaviour of this greenish-brown matter and by other considerations. This greenish-brown material apparently forms the base in which the constituent minerals of the rock are imbedded. Moreover, these slices contain no serpentine, or serpentinous viridite, and no trace of *maschen structur* due to the deposition of opacite, or magnetite, round the edges or along the cracks in olivine crystals . . . . . . The conclusion at which I have arrived, after a careful study of the Rájmahál slices is tha there is not a trace of olivine in any of them."

With regard to some Deccan traps, besides mentioning amygdules stopped by chalcedony, quartz, and zeolites, he also describes No. 3 ball trap, wtth reference to the lacunæ:—

"An orange-coloured substance is rather abundant, and forms a striking object in these slices, regarding which it is difficult to speak very positively. At first sight it looks like a mineral, but it plays the rôle of a glassy base; it is absolutely without external form or cleavage, and nearly all of it is inert between crossed nicols. Occasionally it polarizes feebly in its own natural colour. Closely allied to this is a dark-green substance, which in polarized light is perfectly isotropic. Soaking in hot hydrochloric acid sufficiently long to completely remove the hematite, and magnetite, makes scarcely any impression on the orange substance, and little on the green, that is to say, it removes the green colour, and converts the orange into a dull red but leaves a glass behind absolutely inert in polarized light.

"On the whole, then, I have come to the conclusion that both the bright-orange and the dull-green substances, represent the original magma, or glassy base of the rock, and that they owe their mineral appearance to iron colouration."

Of specimen No. 4, one Tree Hill quarries, Belgaum, he writes—

"The remains of the original glassy base, in part of green colour, and in part reddish-brown, is visible here and there. What I take to be the glassy base exhibits undulating marginal lines of colour that follow the borders of the bounding minerals. This appearance has been described by Zirkel in his "Microscopical Petrography," p. 234, and depicted in plate XI, fig. 1, of that work. Zirkel described this substance as the globulitic base of an altered basalt, metamorphosed into amygdaloidal nests. In the case of the Belgaum rock, however, the metamorphism can hardly have proceeded beyond the colouration of the glassy base, for boiling in hydrochloric acid makes little or no impression on it. It has no action on polarized light."

From some sections that I have recently examined of the Rájmahál rocks I am inclined to put all these substances filling the lacunæ, and in many cases those of

the amygdules, into one category. They seem to belong to those amorphous bodies to which the name Palagonite has been given. In Fouqué and Levy's "Minéralogie Micrographique," plate XXVIII, there is an example of concretions of Palagonite which resemble these substances. MM. Fouqué and Levy define this Palagonite as follows:—"C'est-à-dire une matière amorphe, brunâtre, mamélonée, dévellopée aux dépens du magma vitreux de la roche." It must be noticed, however, that the meaning assigned to the word Palagonite is somewhat different as applied by different authors. It would even seem to be used in another sense by the authors just cited; for in plate LII, fig. 2, they give an instance of olivine partly transformed into Palagonite.

Rosenbusch [1] describes minutely, under the head of Basalt tuffs, both Palagonite rock and Palagonite tuff; and he would seem to regard the substance as originally consisting of "lapilli of basalt glass, in which crystalline secretions have only a minor importance, and which are bound together by cement of various kinds resulting from the hydro-chemical metamorphism of the basalt glass itself."

Rutley [2] states that Palagonite rock "results from the action of heated water, or steam, upon flows of lava," without particularizing if it is the original magma of the flows either in the form of lapilli, or not, which is so metamorphosed.

Dana [3] merely refers to Palagonite as an amorphous mineral belonging to. or near to, the Pinite group.

In spite of these differences of interpretation and definition, I prefer to make use of the word here, and to define these rocks as Palagonite-bearing traps. I am inclined, on the whole, to refer the substances to metamorphosed portions of the original magma; but, as will be seen in the following, some of these forms have a resemblance to olivine, which fact, taken into consideration with the general absence of that mineral from the basic traps of the Deccan and Rájmahál, and with the alleged transformation of olivine into Palagonite (Fouqué and Levy) may have some significance.

But, whatever be their ultimate nature, the following descriptions and drawings of the lacunæ and rock may be of some interest, as a further contribution to the microscopical study of Indian rocks, so ably begun by General McMahon.

A point of great importance, which I may indicate here, is that in some rocks from the Deccan and Rájmahál respectively, the Palagonite substances are almost identical (compare the drawings, figs. 3, 6, 8, and 9, Pl. I); a fresh link in the chain of proof as to the identity of these geographically separated volcanic outbursts.

The following sections were cut for me in the Geological Survey Laboratory, Calcutta: and I am much indebted to my friend Mr. E. J. Jones for the trouble he has taken in selecting and supervising the cutting, of these and other slices.

In none of them is there any indication of mechanical deformation of the minerals; a thing to be expected among gently undulating strata in non-mountainous country.

[1] Mikroskopische Physiographie der massigen Gesteine, p. 747.

[2] Study of Rocks, p. 272.

[3] Text-book of Mineralogy, 4 edn., p. 331.

No. $\frac{1}{441}$.—This is described in the rock register of the Survey as "Amygdaloidal trap." As referred to above, McMahon has described it microscopically, bu he only mentions a zeolite of white and yellowish-red colour as stopping the amygdules.

Since the slices which I have had made of this rock differ in some respects from that description, I may be allowed to make mention of it again in this place. Passing over the general structure of the rock, which needs no further remarks, I will refer only to the amygdules and lacunæ present in it. The large amygdules, which are visible to the eye, are all of a different category from the very small lacunæ which I shall presently notice. One large oval amygdule in the second slice, sent me for micro-chemical testing, was $\frac{1}{4}$ inch across, and was undoubtedly chalcedony. It had a radiating fibrous structure and polarized in aggregate in pale blue-grey colours, displaying a black cross. It resisted scratching with a sharp knife, and was unaltered by acids, hot and cold.

The small lacunæ, which are noticeable in great numbers in other parts of the slice, seem to be entirely distinct from the above. They are more generally of a greenish-brown colour, though some are clear and colourless. The greenish-brown lacunæ have always a very distinct clear marginal, or sub-marginal, border of colourless material; whilst the colourless ones have a distinctly green marginal border. None in my slices of this rock were yellowish red. The shapes taken by these lacunæ are, if one may use the term, squarely amœbiform; that is to say, their main boundaries conform to the boundaries of the felspar crystals among which they lie, or to the cleavage of those crystals, though they have, as it were, put forth numerous blunt processes, very like in shape the pseudopodia of the amœba.

Fig. 1, Pl. I, is a characteristic example of the green kind. It has first a surrounding colourless envelope *a*; secondly, an amber-coloured thin zone *á*, dividing the envelope from the central portion *b*, which is dark greenish-brown coloured, and radially fibrous, the fibres being at right angles to the walls of the lacunæ. The surrounding envelope *a*, in polarized light, changes from light to dark, being dark when *x-y* is parallel or at right angles to one of the nicols. The central portion *b* gives aggregate polarization in its own colour.

In fig. 2, Pl. I, is seen an example of the clear colourless forms, with a border of green material. No structural peculiarities are noticeable in the central portion, such as the radiating structure in the green forms. Under crossed nicols a very faint blue-grey aggregate polarization can be made out in the central portion, resembling that of a fine-grained petrosiliceous rock. The green border polarizes in aggregate, in its own colour, like the central portion of fig. 1. As mentioned by McMahon, these substances invade the crystals of felspar, and sometimes even seem to be included in them, as well as lying between the crystalline contents of the rock.

On testing a portion of the cleaned slice by heating to redness on platinum foil, the results favoured the theory of the zeolitic nature of the substances. All the colourless lacunæ, and many of the felspars, lost their translucent aspect, and became clouded and opaque; whilst the green marginal borders of the former became rusty brown. The green lacunæ also became rusty brown and nearly black, as to their central portion, and clouded and opaque as to their marginal borders.

On the other hand, portions of the fresh slice, tested with acids, showed at first no change in the lacunæ Subsequent boiling with strong hydrochloric acid removed the magnetite from the rock, and began to affect the augite; but, except for absorbing the green colour of the lacunæ there was no other effect on them. A colourless, amorphous substance was left, showing a marginal border, as before.

It seems probable, therefore, that this undissolved substance, inert under polarized light, represents the original glassy magma, among which, however, zeolitic secretions had begun to form, as in the felspars.

No. $\frac{1}{439}$, "Columnar trap, near Agga, Rájmahál" (*Register*).—A fine-grained, black rock. This rock has not been described microscopically before, so far as I know. The mineral-composition of the rock, as revealed by the microscope, is as follows (plate II):—There is a considerable amount of dark-brownish grey confusedly smudged glassy base, the smudging being caused by the great amount of minute specks of magnetite. A prominent feature of the slice is the occurrence of long rods, or rectilinear strings, of magnetite, as though a pen had been tried in all directions across the slice. They are doubtless attempts at crystallization on a large scale. Among this magnetite-saturated base come star-shaped, cruciform, and sometimes fan-shaped, groups of microlites and micro-crystals of triclinic felspar and augite. The augite is generally present as irregularly bounded grains. Here and there (especially noticed in the second slice sent me) basal sections of larger augites were seen with characteristic cleavages. The colour of this mineral is pale yellowish brown. Of frequent occurrence are groups of augite grains and micro-crystals of plagioclase, bound together into inextricably mixed clusters suggestive of having crystallized together. The drawings, figs. 1 and 2, plate I, accompanying McMahon's paper "on the altered basalts of the Dalhousie region" [1] represent this structure so faithfully that they might be taken for drawings of the same rock; especially the one showing the "shooting" of felspar prisms through crystals of augite. Finally, there are larger groups of porphyritic triclinic felspars; all of very clear microtine habit. They have very marked inclusions of magnetite, and a few of augite. In sections at right angles to the composition planes of the common albite twins, these inclusions appear as slender elongations parallel to the prisms; but in sections coinciding with those planes the inclusions are more irregular, numerous, and expanded. They throng the more central portions of the crystals. The grains of augite are often accumulated round the porphyritic crystals of felspar. The porphyritic felspars also show zonal growth bands, which, near the edge of the crystals, besides being poorer in inclusions of the ground-mass, have different polarizing powers to the rest of the crystal. Occasionally, the outer edges of these large crystals are irregular, as if they had been corroded away and had then grown out again irregularly, and simultaneously with the augite. In one crystal I noticed inclusions of micro-crystals of the same mineral. The twinning of the plagioclases is very marked and beautiful, generally in fairly broad lamellæ. From the extinction angles of the microlites, and from those of hemitrope twins, the species is anorthite. The broad lamellæ also indicate a very basic felspar. Twins on the albite pattern are most common; pericline twins very rare, and the combination of the two rare, and on a minute scale.

[1] Records, G. S. I., vol. XVI, p. 186.

There are very many interesting examples of skeleton crystals of plagioclase. As indicated by the drawings, figs. 10 to 16. Pl. I, a straight rod is first formed, the extremities of which then grow out at right angles, and their extremities again at right angles, until a square in outline is formed. To this, which is untwinned, are added apparently buttresses, and a diagonal growth (figs. 14, 15), when twinning becomes apparent. Here again, exactly similar skeleton growths have been described by McMahon in the Dalhousie basalts [1], plate II, figs. 1, 3—7, 10, 12. Enclosures of the base are also common in them.

The larger grains of augite show twinning rarely, and frequently inclusions.

Coming now to the Palagonite lacunæ, they are of a brighter yellow than those of the last slice. One, depicted, fig. 3, is of a roughly hexagonal shape; and generally in this slice they are all more compact in outline, and without the "pseudopodia" noticed in $\frac{1}{441}$. The border in this case appears like the centre of $\frac{1}{441}$; that is to say, it is fibrous, the fibrils radiating at right angles to the walls of the lacuna. Here and there, however, the inner edge of the border is seen to be distinctly mammillated, in which case the fibrils are at right angles to the curved edge. Sometimes, little spherical portions are all but detached from the inner edge of the border; and when that is so, the fibrils radiate from the centre of those spherules. This is distinctly seen in fig. 3. Within the border there is a perfectly hyaline material of the same colour as, but of lighter tint than, the border. Irregular cracks traverse it. Under crossed nicols, whereas the border polarizes in aggregate, the central part gives no effect whatever, except complete darkness faintly tinged with the colour of the substance. It has all the appearance of a structureless glass.

Treating the section with hydrochloric acid removed some of the colour of the Palagonite, but not all.

No. $\frac{14}{29}$, "Basaltic trap: Hills, Dhumni, Rájmahál Hills" (*Register*).—A fine-grained, dark-green, porphyritic rock The general appearance of this rock is very like that of $\frac{1}{441}$. There is no amorphous base, or very little, the ground-mass being finely crystalline. The magnetite is in irregular aggregates, sometimes slightly linear. The felspar appears in micro-crystals, and porphyritic crystals, and the augite in grains without crystallographic form.

The porphyritic plagioclases are similar to those of $\frac{1}{439}$; they are of microtine habit, with inclusions and growth lines. The augite and plagioclase show also an intermingling, as in $\frac{1}{439}$.

The Palagonite lacunæ (fig. 4, plate I) are more irregular than in $\frac{1}{441}$. They penetrate among the crystalline constituents of the rock, moulding them more completely than in the case of $\frac{1}{441}$. Their outlines are sometimes indistinct on one or more sides. In other words their shape does not so much resemble filled-in amygdules, but they seem structurally to occupy the positions where we should naturally expect to find remnants of an amorphous base. There do not seem to be any colourless substances. The coloured ones are greenish or yellowish brown. The radiating fibrous structure almost completely fills the lacunæ, and their marginal border is paler tinted, but not absolutely clear. There is faint aggregate polarization as before, among the fibrous material, and in its own colour.

No. $\frac{65}{19}$, "Trap from a bed of concretionary boulders, Wardah" (*Register*).—A

[1] Records, G. S. I., Vol. XVI, p. 186.

fine-grained, greenish-black rock. This is finer-grained, when seen under the microscope, than the last described, and than $\frac{1}{441}$. Essentially, however, it seems to be much the same. The ground-mass is made up of irregular grains, of pale augite matted together, among which small micro-crystals of plagioclase, somewhat ragged in appearance, are scattered about. The porphyritic plagioclases contain inclusions of the augitic ground-mass, and sometimes of the Palagonite substance. The plagioclase is of the same species as before, judging by measurements of the extinction angles of very good symmetrically twinned lamellæ. The cleavage of the porphyritic crystals is very fine and good.

A few large augite crystals are also developed.

The lacunæ are filled with a brighter, more grass-coloured Palagonite; which does not show any fibrous, or radiating structure, but a very distinct, many-times-repeated zonal structure (see fig. 5, Pl. I).

No. $\frac{14}{2}$, "Basaltic trap (compact): Motighamia Falls, Rájmáhál hills" (*Register*)—A fine-grained, compact, dark-grey rock. Under the microscope it is seen to be finer-grained than even the last. It is built up of a mass of very small granules of augite, magnetite, and micro-crystals of triclinic felspar, with a few large porphyritic ones, the same as in previous slices.

The lacunæ are filled by a pale grass-green substance, without any fibrous structure visible. It appears quite amorphous, save for irregular cracks, and only sometimes possesses a zonal arrangement, as in the last specimen. Most of the lacunæ have lost their substance, leaving holes in the slice.

No. $\frac{7}{312}$, "Dense basalt: N. of Abchund, Malwa, Deccan" (*Register*).—A dirty black, finely crystalline rock. This trap from the Deccan very much resembles those described above from the Rájmahál hills. Its mineral constitution is almost exactly the same (see plate III). There is no uncrystallized magma. It is made up of a set of rather small micro-crystals of triclinic felspar, and grains of augite. The latter is of the same pale colour as in the Rájmahál rocks; but there are some larger crystals of it, some with definite crystalline form, and showing characteristic extinction angles. The magnetite is largely developed, filling up the intervals between the micro-crystals and grains of augite. The porphyritic plagioclases contain inclusions of the ground-mas, and magnetite, these lying, as before parallel to the composition planes of the largely developed albite twins. They belong to the anorthite species, and completely resemble those mentioned above in the nature and appearance of the twin lamellæ.

The lacunæ of Palagonite, fig. 6, Pl. I, are very large and distinct, some in the rock chip being spherical and $\frac{1}{8}$ inch across, and of pale yellowish orange, or golden yellow colour, with clean-cut margins. and dark-brownish orange borders. Their shapes are squarely amœbiform, as in $\frac{1}{439}$ and $\frac{1}{441}$. The borders show numerous dark and light bands, which, seen with high powers, display a fine cross striation (see fig. 7). The central portion of the lacunæ has a mottled or granular appearance and is split up by irregular cracks. Under crossed nicols the dark border evinces a granular aggregate polarization, altogether irregular. The central portion polarizes differently in different lacunæ. In some the outer edge of the central portion remains faintly illuminated, and of a deep green colour, whilst the very central portion is dark. In others the central portion appears split up into dark, and faintly

illuminated patches, which, on revolving the stage, resolve themselves into a set of conflicting dark and light crosses, which travel with the revolving stage, but at twice the rate, completing a revolution of 360° whilst the stage has only gone through 180°. Some lacunæ contained a dark dusty-looking, colourless substance, others contained the latter in combination with the yellow and orange substance, sometimes in stripes. Under polarized light they gave uncertain changes from light to dark.

On treating the uncovered slice with cold, strong hydrochloric acid, the colour of the Palagonite substances began to be absorbed in a few moments. Repeated treatment in this way soon dissolved away all the colour, and, with it, all structural differences between the margins and the central portions. At the edges of the slices, where the acid had barely spread, the change from the bright orange substance with its marginal border, zonal lines, and fine cross striation, to the structureless and colourless substance acted on by the acid could be well seen.

Heating a portion of the slice to redness on platinum foil changed the orange colour to a dark red; subsequent boiling of the slice in acid gave no result owing to the slice going to pieces, and to the marking of the effects by other changes in the magnetite and augite.

On the other hand, it was very simple to isolate fragments of the Palagonite from the rock chip from which the slice was taken, and treat them chemically. Several of these, individually transferred to a glass slide, were drawn, and then treated with acid and heated. After the colour had been removed, and all the structure gone, except the irregular cracks, they were heated to ebullition with fresh acid, ten or twelve times, and steeped all night in cold acid. The outlines, when drawn again, were the same as before the test. A clear, colourless, unaffected glass remained, without structure (except cracks), and which, very carefully tried with polarized light, remained completely inert.

It would seem, therefore, that there was originally, both in the central and marginal portions, a zeolitic substance, developed in or from the glass of the Palagonite substance, and which became absorbed by the acid, leaving the glass behind.

No. $\frac{14}{30}$, "Basaltic trap, with zeolites: hills S. of Dhumni, Rájmahál Hills" (*Register*).—A fine-grained, dark-green rock, with amygdules. This appears to be from the same locality as $\frac{14}{20}$. It resembles the latter closely, but in the Palagonite lacunæ there are some differences.

Under the microscope it is seen to be a fine-grained rock, with very contrastingly-large porphyritic plagioclase felspars. The felspars are anorthite, as before, the angle between two hemitrope extinctions of albite twins measuring in one case 72°. There is no uncrystallized base, the ground mass being made up of very minute irregular grains of augite of pale colour, mixed with microlites of anorthite and magnetite. This crystalline ground-mass is finer in the vicinity of the larger porphyritic felspars.

The slice possesses a larger number of lacunæ than any above described. The rock chip sent with the slice, as in the previous case, contained (plainly visible to the eye) spherical aggregates of Palagonite, $\frac{1}{8}$th of an inch across, besides the smaller ones just visible as specks.

Under the microscope they show very little structure individually, and are of various shapes, generally irregular, and without pseudopodial processes (figs. 8, 9, Pl. I).

Their colouring varies from an exceedingly brilliant orange to pale grass green. Patches of the slide have all the lacunæ tinted one colour, and other patches tinted another, between which there is a set of lacunæ showing intermediate colours. From this it is abundantly evident that the colouration is a superinduced phenomenon, affecting different portions of the rock differently in groups or bands.

As a rule, the marginal border is only faintly seen by ordinary light in the case of the orange Palagonite lacunæ, whereas some of the green ones have a very marked zonal structure throughout. The orange-coloured substance, like the golden yellow substance of $\frac{1}{17}$, is roughly marked with an irregular granular structure, and traversed by irregular cracks. Under crossed nicols the margins come out a lighter colour, polarizing in aggregate, whilst the central portion remains almost completely dark: sometimes a faint change appearing in some of the lacunæ. In one (fig. 8) there is a finely dotted, sub-central portion, which is lighter under crossed nicols and with fine aggregate polarization, like the margins. The shapes and cracks of some of these lacunæ, at first sight, suggest a resemblance to olivine grains. There is no trace, however, here, as elsewhere, in these rocks, of normal unaltered or serpentinized olivine.

The large porphyritic crystals of plagioclase contain small Palagonite lacunæ, as well as inclusions of magnetite; and they are streaked along their cleavages by a yellow-colouring matter, which runs continuously into connection with certain of the Palagonite lacunæ.

These substances resemble most nearly those described by McMahon under the head of "No. 3, Ball trap"

Heating on platinum foil, and boiling a portion of the slice in acid, gave no good results, as in the case of $\frac{1}{17}$; but I was able again to isolate portions from the chip and treat them as in the last case. The only difference noticeable was that the whole of the colour was not absorbed, the grain of Palagonite remaining at the end a pale brownish yellow. It acted as a simple glass under polarized light. The general resemblance between the Palagonite substance of this rock from the Rájmahals, and of the last from the Deccan, is very noteworthy, both microscopically and macroscopically.

No. $\frac{4}{7}$, "Basaltic trap, with zeolites; Burnait valley, Rájmahál hills" (*Register*).—Light, dirty green, fairly fine-grained rock. This rock had fallen to pieces in the grinding. As it resembles $\frac{1}{17}$ almost completely, it needs no separate description. There is the same, blurred, glassy base, the same lines of magnetite, granular augite, and plagioclase crystals, showing all stages of growth from skeleton crystals. Lastly, the Palagonite lacunæ were the same in colour, shape, and structure.

In conclusion, I would state that, though I consider these substances described in this paper as undoubtedly belonging to what has been called Palagonite, I would not absolutely bind myself to the view either that they are metamorphosed, or zeolitized, portions of the original glassy magma (though I lean to this view), or that they are pseudomorphs after olivine. It may be remarked, however, that in the Manual of the Geology of India,[1] some of the Rájmahál traps are said to contain olivine in large quantities.

[illegible]

Fig. 1.

Fig. 2.

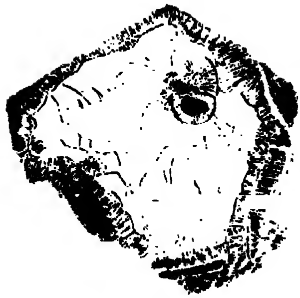

Fig. 3.

Fig. 4.

Fig. 5.

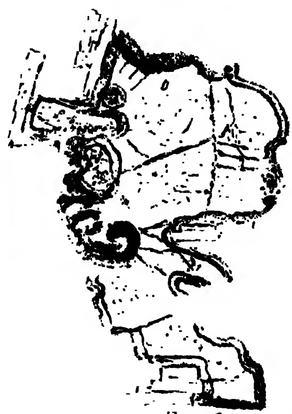

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 10.

Fig. 9.

Fig. 11.

Fig. 13.

Fig. 15.

Fig. 12.

Fig. 14.

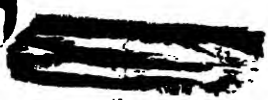

Fig. 16.

Plate I.

Plate II.

Plate III.

REFERENCES TO PLATES.

Plate I, figs. 1 to 6, 8 and 9, lacunæ of Palagonite, as seen under the microscope by ordinary light; fig. 7, enlarged border of fig. 6, showing cross striation; figs. 10 to 16, skeleton crystals of plagioclase.

Plate II, Slice of a Rájmahál trap, No. $\frac{1}{416}$, seen under the microscope by ordinary light.

Plate III, slice of a Deccan trap, No. $\frac{1}{512}$, seen under the microscope by ordinary light.

Notes on Tin Smelting *in the* Malay Peninsula, *by* T. W. HUGHES HUGHES, C E., A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.*

The native method of tin smelting in vogue in the Malay Peninsula and the Tenassarim Province of Burma, has been described by various writers who have touched on the subject of the mineral resources of those parts of the world.

There are two varieties of furnaces for the reduction of ore;—one in which a natural draught is depended on, and the other where the blast is artificially applied. The latter is the only furnace that I have seen in operation; but Mr. Treacher, Secretary to Government, Perak, tells me that the other was in common use in the back parts of the State to the end of 1888, when legislation prohibited its continuance, on the ground that to feed it charcoal, made from the hardest and most valuable timber in the forests, had to be employed.

The blast furnace known as the Tonka type is the prevalent one in all the large smelting yards, and there is a general belief amongst the Chinese owners and their admirers that it cannot be improved upon for economy in working. This view is in some measure supported by the fact that at Taiping an attempt to in.roduce the ordinary European system of treating ore has not been a triumph. The cause of failure, however, did not, in my opinion, lie in the system, but rather in some defect of management or of measures; for, while at Singapore, passing on my way to Australia, I had the pleasure of visiting a successfully conducted enterorise, worked entirely, on the lines of an English undertaking, thus showing that, with proficient direction the expedients of western metallurgical skill could throw into shade the modest operations of native effort.

Under the title of the Straits Trading Company, Limited; large smelting works, consisting of a burning house, two reducing and refining furnaces. and necessary appliances, have been erected on Pulo Brani, which faces the New Harbour, and is separated by a narrow strait of about half a mile in width from the Island of Singapore. The Manager, Mr. John McKillop, explained to me the whole process as carried out by him, from the calcining of the raw ores to the tapping of the metal; and showed me the laboratory where assays of ore and tin were constantly being made.

I am not at liberty to enter into the details of all I observed, the Works being still "private" and strangers not ordinarily admitted, but I have permission to publish the few particulars that follow.

Ore.

The raw tin stone is obtained chiefly from the Malay States of Perak, Salangore, and in less quantity from Negri Sembilan and Singapore. Lower class ore can be accepted by the Company than the native smelter will deal in, and, as their financial transactions are ready money ones, they obtain an important advantage in purchasing.

Fuel.

The principal impurities are mundic, arsenical pyrites, and wolfram—the latter being a very unwelcome associate. The fuel used is Welsh anthracite and Australian Bulli coal, a bright bituminous variety. I advised a trial of such of our Assam and Bengal coals as contained a fairly high percentage of fixed carbon, as, if found suitable, of which I had no misgiving, it would then be a question of relative effect and cost, whether they obtained a footing so far south.

Slag.

The charge was 1¼ of coal to 1 of ore, and the resulting slag contained 20 to 25°/₀ of tin. This slag is treated separately, and, Mr. McKillop says, is resmelted with scrap iron and coral limestone, yielding tin and a slag carrying ·25 to ·50 per cent. of tin, which is thrown away.

Analysis of tin.

The analysis of their purest commercial tin is—

Sn.	99·97°/₀
Fe.	·03°/₀
TOTAL	100·00

This is a much higher quality than that of Perak tin, the analysis of which by Karsten is—

Sn.	95·66
Fe.	·07
Pb.	1·93
Bi.	2·34
TOTAL	100·00

Mr. McKillop has promised to send samples of ores and metal to our Geological Museum, and also the results of his long series of assays. These will be very interesting, and must add further repute to the inauguration of progessive science.

CALCUTTA;
14th October 1889.

Provisional Index *of the* Local Distribution *of* Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones *in the* Indian Empire *By* W. King, B.A., D. Sc., *Director of the Geological Survey of India.*

An urgent demand having been made for an Annual Statement, showing the quantities and value of mineral products in British India, for publication in the *Mining and Mineral Statistics of the United Kingdom of Great Britain and Ireland;* it is thought that a considerable amount of help may be afforded to the local authorities, in their compilation of returns for the formation of the statistics required, by issuing an Index such as this professes to be. It must necessarily be a provisional issue, because the information in hand up to date is, to a very large extent, except in the matters of coal, salt and gold, very isolated, fragmentary, and, in many cases, only that of hear-say. There is also as yet considerable hesitation as to the class "Important Minerals" in India as compared with "Important Minerals" in Great Britain, many of the latter being still only known in India by traces, or as —owing to absence of fuel—of really little or no immediate importance.

The system of classification of useful minerals adopted in this Index is thus open to considerable modification or improvement; or the whole plan of the Index itself may ultimately require re-arranging; but, such as it is now, it is put forward and will be continued in issues of the Records until the whole is sufficiently complete and satisfactory to be published in a volume by itself. I would ask, however, as these issues appear, that all who are in any way interested in the comnletion of the Index, would obligingly send in to the Survey corrections of errors of omission or commission; and at the same time supply such information as may be within their own observation or ken.

In this Index the following arrangement of Presidencies, Provinces, Agencies, or Native States has been adopted, each being taken in its alphabetical order:—(1) Assam, (2) Bengal, (3) Bombay (including Sind, &c.), (4) Burma, (5) Central Provinces, (6) Madras (including Travancore, Cochin, Vizianagram, &c.), (7) North-West Provinces and Oudh, and (8) Punjab. *Native States.* (I) Afghanistan, (II) Baluchistan, (III) Central India and Rajputana, (IV) Kashmir, (V) Mysore and Coorg, (VI) Nizam's Dominions, (VII) Nepal, Sikkhim and Thibet.

The Mineral Products are taken under the following headings:—*Important Minerals,* including:—Coal, Iron ores, Gold, Petroleum, and Salt; *Miscellaneous Minerals* including:—Alum, Antimony Ores, Arsenical Minerals, Asbestus, Bismuth and Cobalt Ores, Borax, Chrome Ores, Copper Ores, Corundum, Gypsum, Lead Ores, Magnesia Minerals, Manganese Ores, Mica, Natron, Nitre, Ochres, Phosphates, Platinum, Plumbago, Soapstone, Soda Salts, Sulphur, Tin Ores, Zinc Ores; *Gem Stones,* including:—Amber, Beryl, Diamond, Garnet, Jade and Jadeite, Quartz, &c., Rubellite, Ruby, Sapphire, Spinel; and *Quarry Stones,* including:—Clays, Granite (Gneiss, &c.), Laterite, Limestone (Marbles, Kunkar, &c.), Slate, and Trap.

The following contractions have been adopted:—

Man. = Manual of the Geology of India.
Mem. = Memoirs of the Geological Survey of India.
Rec. = Records of the Geological Survey of India.
Mus. = Museum of the Geological Survey of India.

ASSAM.

IMPORTANT MINERALS.

Coal, *C.* Iron Ores, *I.* Gold, *G.* Petroleum, *Oil.* Salt, *Sal.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL, *Symbol C.*	CACHAR.			
	DARRANG—			
	Barnadi R. . .	Stat. Acct. I. 137 .	G. COR.	
	GARO HILLS—			
	Darrang-giri .	Man. III. 106 .	...	Cretaceous; promising; area of field, 20 sq. miles, 76,000,000 tons.
	Garegittam, (a place in the Darrang-giri field).	Mus.		
	Harigaon . .	Man. III. 106 .	...	Not of much value.
	Rongrengiri . .	" " .	...	
	Somesari R. . .	Rec. XX. 41 .	...	
	Siju . .	" " .	...	
	KHASI AND JAINTIA HILLS—			
	Amwi . .	Man. III. 109 .	...	Nummulitic.
	Borsora . .	Rec. XVI. 164 .	...	Cretaceous.
	Byrang . . .	Man. III. 108 .	...	Nummulitic.
	Cherra Punji . .	" 109 .	I. GRT. LIM.	Ditto, approximate quantity, 1,184,369 tons.
		Rec. XXII. 167 .	SND.	
	Jarain . .	Rec. XVI. 199 .	..	Cretaceous.
	Langrin . .	Rec. XVII. 143 .	SND. .	Ditto 30 sq. miles. Very promising.
	Lairungao . .	Man. III, 108.		
	Lakadong . .	" 109 .	...	Nummulitic, 1,500,000, tons.
	Maodon . .	" 108.		
	Maolong . .			
	Maonaichora . .			
	Maostoh . .			
	Maosynram . .	...	...	63,000 tons.
	Maobelarkar . .	...	TRP. .	Cretaceous; small field, 52,000 tons.
	Narpur . .	Man. III. 109 .	...	Nummulitic.
	Shatyngah . .		...	Ditto.
	Shella . .	Man. III. 108.		
	Shermang . .	" 109.		
	Thanjinath . .	" 108.		
	SINGPHO HILLS—			
	Upper Dehing R. .	Rec. XIX. 111.		

ASSAM—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL—*contd.*	NAGA HILLS—			
	Dikhu . .	Mem. XII. 354 .	ALM.	
	Dirak Nadi . .	" 311 .	...	Makum field.
	Disai field . .	" 355 .	G. OIL .	Poor, badly situated.
	Disang . .	" 353 .	OIL SND. .	Good, but out of the way.
	Jaipur field . .	" " .	I. OIL PLT.	Better. .
	Janji field . .	" 355 .	G. . .	Small, comparatively unimportant.
	Makum field . .	" 304 .	...	Worked.
	Nazira field . .	" 328.		
	Rangring . .	" 309, 348	...	Makum field.
	Saffrai R. . .	" 332,346, 348.	OIL . .	Nazira field.
	Tel Pung . .	" 293. 337, 348.	I. OIL LIM. SND.	Ditto.
	Tirap . . .	" 305, 348	...	Makum field.
	Tiru Nadi . .	" 332, 348	OIL . .	Nazira field.
	Wakang Jan . .	" 336, 348	...	Ditto.
	NOWGONG—			
	Dhaneswari R. .	Stat. Acct. I. 176 .	LIM.	
	Jamuna R. . .	" " "	LIM.	
	SIBSAGAR—			
	Doigrung R. . .	Rec. XVIII. 31 .	LIM.	
IRON ORES, *l.*	GARO HILLS—			
	Lakkiduar Range .	Mus.		
	GOALPARA—			
	Dhubri . .	Mus.		
	KAMRUP . .	Stat. Acct. I. 21 .	LIM.	
	KHASI AND JAINTIA HILLS—	Mus. . .	C. G. COR. GRT. LIM. SND. TRP.	
	Cherra Punji .	Mus.	C. GRT LIM.	
	Lailangkot . .	Mem. I. 202 .	SND. . .	Washed iron sand.
	Molim . .	Mem. I. 202 .	SND. . .	Washed iron sand.
	Nonkrim . .	Mem. I. 202 .	SND. . .	Washed iron sand.
	Noyandri . .	Stat. Acct. II. 235.	...	Industry died out. In 1858, export 45,000 maunds.
	NAGA HILLS—	Mus. .		
	Dholbagan . .	Mem. XII, 296, 360		
	Jaipur . .	" 273 .	C. OIL PLT.	
	Tel Pung . .	" 290, 359	OIL LIM. SND.	
	Tirugaon . .	" 359, 360	OIL . .	Saffrai valley, hill east of, clay-iron stones. Once worked a good deal by the Assamese.
	SIBSAGAR—			
	Giliki Guard . .	Mem. XII. 297 .	...	Partly in Naga Hills.
	Golaghat . .	Mus. . .	...	Partly in Naga Hills.
	Naphuk . . .	Mem. XII. 297, 360	...	Partly in Naga Hills.

ASSAM—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
GOLD, *G.*	DARRANG—			Mostly auriferous sands.
	Bargang R.	Man. III. 223.		
	Bhairavi R.	" "		
	Bharoli R.	" 222.		
	Burigang R.	" "		
	KHASI AND JAINTIA HILLS—			
	Bogapani Nadi, Moflang.	Man. III. 227.		
	LAKHIMPUR—			
	Borpani R.	Man. III. 225.		
	Dibong R.	" 226.		
	Digaro R.	" "		
	Dihong R.	" 225.		
	Dikrang	" "		
	Joglo R.	" 226.		
	Noa Dihing R.	" 227.		
	Parghat	" 224	PLT.	
	Sadiya	" "		
	Sirsi R.	" 225.		
	Subansiri R.	" 225 and Rec. XVII. 192.		
	Tengpani Mukh	Man. III. 224.		
	SIBSAGAR—			
	Bari Dihing R.	Man. III. 224.		
	Dhaneswari R.	" 223	C. LIM.	
	Disai R.	" "	C. OIL.	
	Jangi R.	" 224	C.	
	Pakerguri R.	" "		
PETRO-LEUM, *Oil.*	CACHAR—			
	Barak R.	Man. III. 138.		
	Sarung R.	Stat. Acct. II. 370.		
	Siltee	" " 137.		
	SIBSAGAR AND NAGA HILLS—			
	Bari Dihing R.			
	Disai Valley	Man. III. 137 (Also Mem. XII, 357.)	C. G.	
	Disang R.	" 136	C. SND.	
	Hil Jan. N.	" 137.		
	Jaipur	" 136	C. I. PLT.	
	Makum N.	" 134.		
	Namchick Pathar	" 133.		
	Saffrai R.	" 137	C.	
	Sarang R.	" 138.		
	Supkong	" 133.		
	Tel Pung, Dikhu R.	" 137	C. LIM. SND.	
	Tiru Nadi	" "	C.	
	SINGPHO HILLS—			
	Tirugaon, Upper Dehing.	" "	I.	

ASSAM—*continued.*

IMPORTANT MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
SALT, *Sal.*	CACHAR	Stat. Acct., II. 370	LIM.	Salt.
	LAKHIMPUR— Borhat	Man. III. 491.	...	Springs; yielded in 1809, 100,000 maunds of salt.
	Sadiya	" "		
	NOWGONG— Jungthang, Mikir hills	Stat. Acct. I. 176.	...	? Salt Mine.
	SIBSAGAR— Jaipur	Mem. XII. 356	...	Saline springs, formerly utilized by the Assamese.

MISCELLANEOUS MINERALS.

Alum, *Alm.* Antimony Ores, *Ant.* Arsenical Minerals, *Ars.* Asbestus, *Asb.* Bismuth and Cobalt Ores, *B.C.* Borax, *Bx.* Chrome Ores, *Chr.* Copper Ores, *Cop.* Corundum, *Cor.* Gypsum, *Gyp.* Lead Ores, *Ld.* Magnesia Minerals, *Mag.* Manganese Ores, *Man.* Mica, *Mi.* Natron, *Nat.* Nitre, *Nit.* Ochres, *Och.* Phosphates, *Pho.* Platinum, *Plt.* Plumbago, *Plm.* Soapstone, *Sop.* Soda Salts, *Sod.* Sulphur, *Sul.* Tin Ores, *Tn.* Zinc Ores, *Znc.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
ALUM, *Alm.*	SIBSAGAR— Dikhu Valley	Mem. XII. 361; Mus.	C.	From pyritous shales of coal measures, might be manufactured profitably.
COPPER ORES, *Cop.*	MUNIPUR— Kubo Valley	Man. III. 278.		
CORUNDUM, *Cor.*	DARRANG	Stat. Acct. I. 139	...	Small quantity.
	KHASI AND JAINTIA HILLS— Nongryniew	Man. III. 426	...	Worth attention.
MAGNESIA, MINERALS, *Mag.*	MUNIPUR— Kasom.			
PLATINUM, *Plt.*	SIBSAGAR— Jaipur Noa Dihing, R.	Mus. Man. III. 168	C. I. OIL. G.	
SULPHUR, *Sul.*	NOWGONG— Mikir and Rengmah Hills.	Mus.		

ASSAM—*continued.*

GEM-STONES.

Amber, *Amb.* Beryl, *Brl.* Diamond, *D.* Garnet, *Gar.* Jade, and Jadeite, *Jd.* Quartz, Q Rubellite, *Rbl.* Ruby, *R.* Sapphire, *S.* Spinel, *Spl.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
QUARTZ, *Q.* (Includes rock-crystal and the various forms of quartz, as Agate, Amethyst, Blood-stone, Chalcedony, Chert, Flint, Jasper, Onyx, Opal, &c.)	KHASIA AND JAINTIA HILLS— Maram . .	......	...	Amethystine quartz.

No further reliable information.

QUARRY STONES.

Clays, *Cly.* Granite, Gneiss, &c., *Grt.* Laterite, *Lte.* Limestone, Marbles, Kunkar, &c., *Lim.* Slate, *Slt.* Trap, Basalt, &c., *Trp.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
CLAYS, *Cly.*	LAKHIMPUR—			
	Brahmakhund . .	Man. III. 567 .	...	Kaolin. Very out of the way.
	Bora . .	" "		
	GARO HILLS—			
	Tura . .	Rec. XX. 42 .	GRT. .	White shaly indurated clay; thick deposit.
	Western end of range	Man. III. 567 .	...	Fine white clay, base of cretaceous rocks.
	GOALPARA—			
	Goalpara . .	Mus.		
	NAGA HILLS—			
	Ledo Coal Mine .	Mus. . .	C.	

ASSAM—*continued.*

QUARRY STONES—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
GRANITE, &c., *Grt.*	CACHAR—			
	Kopili R. . .	Mus. . . .	LIM.	
(Includes all fairly compact crystalline rocks; as gneisses of all kinds, generally of grey greenish or flesh colors. Not compact massive black or dark-green rocks such as Basalt, Trap, &c.)	DARRANG—			
	Tezpur . .	Mus.		
	GARO HILLS— . .	Man. III. 535.		
	KAMRUP—			
	Kamaikia .	Mus.		
	KHASIA AND JAINTIA HILLS—			
	Cherra Punji .	Mus. . . .	C. I. LIM. SND.	
	Lailangkot . .	"		
	Molim . .	"		
	Nongepang . .	"		
	Nônglang . .	" . . .	TRP.	
	Surarim . .	"		
	NAGA HILLS—			
	Nambar Falls . .	Mus. . . .	C. LIM.	
LIME-STONE, &c., *Lim.*	CACHAR.			
(Includes most marbles of different kinds, calcareous, flag-stones, Kunkar or Ghutin, Travertine. Also, for convenience, serpentines and alabaster.)	Gunjung . .	Rec. XVI, 243.		
	Quilong . .	" 203 .	...	Travertine, or kunkar.
	DARRANG—			
	Mangaldai Sub-Divn.	Mus.		
	GARO HILLS—		GRT.	
	Arnok . .	Rec. XX. 41 .	...	Cretaceous limestone, vertical beds.
	Damalgiri . .	" 42.		
	Khalupara . .	Mus.		
	Rongkon Stream .	"		
	Siju . .	Rec. XV. 178 .	C.	
	KAMRUP—			
	Foot of Bhutan Hills .	Stat. Acct. 121 .	I. . .	Apparently travertine: good quarry.
	KHASI AND JAINTIA HILLS—			
	Bhawal . .	Stat. Acct. II. 234		
	Borsora . .	Rec. XVI. 164 .	C. . .	Large quarries. Inglis & Co.

ASSAM—*continued.*

QUARRY STONES—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
LIMESTONE —*contd.*	KHASI AND JAINTIA HILLS—*contd.*			
	Borpungi . .	Stat. Acct. II. 234	...	Supply inexhaustible: goes by the name of Sylhet Lime. Export in 1876-77; 1,600,000 maunds. Revenue R67,626. Khasi Chiefs' Revenue more than £2,000.
	Borsyrmai . .			
	Byrang . .			
	Chunchhora . .			
	Chunjura . .			
	Dholai . .			
	Dwara . .			
	Ichhamati . .			
	Lamapushi . .			
	Langrin . .			
	Lithang . .			
	Longlong . .			
	Lumdihlong . .			
	Maoni . .			
	Maodon . .			
	Maokartilla . .			
	Maolong . .			
	Moheshkali . .			
	Myrlipungi . .			
	Nongtha-long . .			
	Nokria . .			
	Patharia . .			
	Ramsengraiskeh .			
	Rowai . .			
	Rupnath . .			
	Shella . .			
	Silai . .			
	Sohlai . .			
	Tharia Ghat . .			
	NOWGONG—			
	Panimur . .	Stat. Acct. I. 176.		
	SIBSAGAR—			
	Doigrung . .	Rec. XVIII, 32 .	C.	
	Nambar R. . .	Mem. IV. 412 .	C. GRT.	
	Tel Pung. Dikhu Valley . .	„ XII.		
	SYLHET—			
	Bagoli . .	Rec. XVII. 114 .	...	Foot of Langrin Coal-field. Worked by Inglis & Co. Burnt at Sonamganj. Output 1888-89, 1,223,570 maunds.
	Lokma . .	„ 145.		
SAND-STONES, *Snd.*	DARRANG . .	......	COR.	
(Includes any sandy rock used for building,	GARO HILLS—			
	Ganchi.			
	Puthimari.			
	Rongphagiri.			

ASSAM—*concluded.*

QUARRY STONES—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
SAND-STONES —*concluded.* (even calcareous sandstones, flags. Also quartzites, which are only indurated sandstones, pebbly rocks.)	GARO HILLS—*contd.*			
	Rongphar stream.			
	Sumesari.			
	Do. R.			
	KHASI AND JAINTIA HILLS—			
	Cherra Punji .	......	C. I. GRT. LIM.	
	Liam.			
	Shillong.			
	Umblay R.			
SLATE, *Slt.* . (Includes flags, though these are cleaved like slates.)	KHASI AND JAINTIA HILLS—			
	Moflung . .	Mus.		
	Umiam . .	"		
TRAP, &c., *Trp.* (Includes basalt, whinstone, and other compact massive dark colored rocks.)	KHASI AND JAINTIA HILLS—			
	Lime Glen . .	Mus.		
	Maomlu . .	"		
	Maubelarkar .	"	C.	
	Nonglang . .	"	GRT.	
	Soktia . .	"		
	Tharia R. . .	"		
	Tharia Ghat. .	"	LIM.	

BENGAL.

IMPORTANT MINERALS.

Coal, *C.* Iron Ores, *I.* Gold, *G.* Petroleum, *Oil.* Salt, *Sal.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL, *C.* .	BHAGULPUR—			
	Bramini R. . .	Man. III. 78; Mem. XIII. Part I.	TRP. SND.	
	Chapurbita . .		"	Being tried by boring.
	Hura . .			
	Mhowagarhi . .			
	Pachwara . .			
	BURDWAN—			
	Barakar . .	See Raniganj .	I. LIM. SND.	Pits.
	Jainti . .	Man. III. 78; Rec. VII. 247.		
	Kundit Karaiah .	Man. III. 78.		

BENGAL—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stones.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL—*contd.*	BURDWAN—*contd.*			
	Laikdih . .	......	SND. . .	Open quarry, with seam of coal over 70 feet thick, worked by Bengal Coal Company.
	Raniganj . .	Man. III. 81; Mem. III, Part I.	LIM. SND. .	500 square miles. Estimated quantity, 14,000 million tons. 44 collieries. Raniganj is the general name for the field. Messrs. Apcar and Company, working Churanpore Colliery, expect to put out for 1889-90 2,000 tons. The output of the Bengal Coal Company for the year ended April 1889, was 213,119 tons. The New Beerbhoom Coal Company's output for the half-year ending April 1889, was 3,207,849 maunds. The Raniganj Coal Association for the year ending March 1889 raised 1,391,591 maunds.
	Sahajori . .	Man. III. 78.		
	Sanktoria . .	" 78; Mem. III, Part I.	SND. . .	Pits.
	CHOTA NAGPUR—			
	Aurunga . .	Man. III. 85; Mem. XV. 55.	I. LIM. SND.	97 square miles. 20 million tons.
	Bisrampur . .	Man. III. 88; Rec. VI. 81.	...	400 square miles.
	Bokaro . .	Man. III. 83; Mem. VI. 39.	...	220 square miles, 1,500 million tons.
	Chopé . .	Man. III. 85; Mem. VIII. 347.	...	1 square mile.
	Daltongunj . .	Man. III. 87; Mem. VIII.	COP. .	200 square miles. 11 million tons.
	Giridih . . .	......	...	Pits. East Indian Ry. Co. Bengal Coal Company.

BENGAL—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL—*contd.*	CHOTA NAGPUR—*contd.*			
	Hutar . .	Man. III. 86; Mem. XV. 91.	SND. .	78 square miles.
	Irea . .	Man. III. 87; Mem. XVII.		
	Itkuri . .	Man. III. 85 .	...	Half a square mile.
	Jhilmilli . .	„ 88; Mem. XXI. 205.	...	35 square miles.
	Jharia . .	Man. III. 83; Mem. V.	...	200 square miles. 465 million tons.
	Karanpura N. & S. .	Man. III. 85; Mem. VI.	...	472 and 72 square miles. 8,750 million tons, and 75 million tons.
	Karharbari . .	Man. III. 78 .	SND. .	8½ square miles, estimate, 136 million tons. Output of Bengal Coal Company, ending April 1889, 109,160 tons, E. I. R. Company, for half-year ending June 1889, 260,924 tons, Raniganj Coal Association, for year ending March 1889, 2,675,743 maunds.
	Lakhanpur . .	Man. III. 89.		
	Morne . .	„ 87; Mem. XVII.		
	Ramgarh . .	Man. III. 84; Mem. VI. 109.	...	40 square miles.
	Ramkola.			
	Rampur . .	Man. III, 89.		
	Tattapani . .	„ 87; Mem. XV. 21.		
	Udaipur . .	Man. III. 89 .	G. SND.	
	ORISSA—			
	Patrapara . .	Man. III. 75; Mem. I. 33.	G. SND. .	700 square miles. Inferior.
	Talchir . .			
	RAJSHAYE—			
	Daling . .	Mem. XI, .	COP. TN.	
	Jainti R. . .			
	Pankabari . .			
	Tindaria . .	......	...	Tried, but found to be too much crushed; might make briquettes.

BENGAL—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
IRON ORES, *I.*	BHAGULPUR—			
	Kharakpur Hills .	Man. III. 367 .	SLT. SND.	Lateritic ores.
	BURDWAN—			
	Ballia . .	Man. III. 364.		
	Barakar . .	...	C. LIM. .	Clay ironstone, Bengal Iron Works.
	Deocha . .	Man. III. 362.		
	Dumra . .	" "	...	Lateritic ore largely.
	Goanpur . .	" "		
	Narainpur . .	" "		
	CHOTA NAGPUR—			
	Balunagar . .	Man. III. 378; Mem. XV. Part 1.	LIM. . .	To the north of; 4 square miles, manganiferous.
	Chaibassa . .	Man. III. 375.		
	Gangpur . .	" 381 .	C.	
	Jashpur . .	" " .	G. . .	Lateritic ore.
	Kasai R. . .	" 374 .	...	Bedded magnetite.
	Palamow . .	" 376 .	...	Remarkable abundance of ores.
	Rajbar . .	" 377; Mem. XV. 112.	...	Ferruginous shales.
	Tiludih . .	Man. III. 374 .	...	Magnetic iron.
	DACCA—			
	? Madapur Jungle .	......	...	? Lateritic ore.
	ORISSA—			
	Talchir State . .	Man. III. 361; Mem. I. 11.	C. G. SND.	Ironstone, shales, or lateritic ore.
	Ungul State . .	Man. III. 361; Mem. I. 11.		
GOLD, *G.* .	BURDWAN—			
	Dalkissar (Bankura) .	Man. III. 189 .	...	Sands.
	Kasai R. (Midnapur).	" " .	...	And tributaries. 21 gold washers.
	CHOTA NAGPUR—	Rec. II. 11.		
	Asantaria (Singhbhum).	Man. III. 194.		Sands.
	Bajragi (Udaipur) .	" 197.		
	Bakaruma . .	" 199.		
	Bamni R. (Manbhum)	" 192.		
	Bhagmundi (")	" 190.		
	Bonai (Trib. States) .	" 195.		
	Chaibassa . .	" 192 .	COP. SLTE. SND.	
	Dalma Hills (Manbhum).	" 192.		
	Dhipa . .	" 193.		
	Hisatu . .	......	LD.	
	Ichagarh . .	Man. III. 193.		
	Jamargi . .	" 199.		

BENGAL—*continued.*

IMPORTANT MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
GOLD, *G.*—*contd.*	CHOTA NAGPUR—*contd.*			
	Jashpur (Trib. States)	Man. III. 196 .	I. . .	Nugget in Museum.
	Kamerara (Singbhum)	" 193.		
	Kamhar (Udaipur) .	" 199.		
	Kappargadi Ghat .	" "		
	Karkari R. (Manbhum)	" 192.		
	Kasai R. (")	" "		
	Khandrajah (Udaipur)	" 199.		
	Koweri R. (")	" 192.		
	Landu . .	" 194.		
	Namra . .	" 192.		
	Pharsabahal . .	" 197.		
	Porahat . .	" 193.		
	Rabkob . .	" 194.		
	Salka . .	" 199.		
	Saranda . .	" 195.		
	Sonapet . .	" 194 .	...	Nugget-like fragments have been found; sands generally.
	Subhanarekha R. .	" 192.		
	Supur (Manbhum) .	" "		
	Tutko R. (Manbhum)	" "		
	Udaipur . .	" 194.		
	DACCA—			
	Tipperah? . .	Man. III. 228 .	...	On authority of Tavernier.
	ORISSA—			
	Brahmani R. . .	" 189 .	...	Sands.
	Dhenkanal . .	" 188.		
	Keonjhar . .	" "		
	Ouli R. . .	" 189.		
	Pal Lahara . .	" 189; Mem. 1·88.	...	Sand, said to be worked considerably.
	Tikaria R. . .	Man. III, 189.		
PETROLEUM, *Oil.*	CHITTAGONG?			
SALT, *Sal.* .	CHITTAGONG—			
	Bangamura . .	Man. III. 491 .	...	Salt lick.
	Mawdangklang .	" " .	...	Ditto.
	Lungshem range .	" 492 .	...	Two salt springs.
	Sorphuel Hill . .	" " .	...	Salt spring.
	ORISSA—			
	Balasore . . .	Man. III. 477 .	...	Artificial.
	Puri . . .	......	...	Artificial. ∴ Chilka Lake.
	PATNA—			
	Behar . . .	Man. III. 477 .	...	Indirectly, from the Saltpetre factories.

BENGAL—*continued.*

MISCELLANEOUS MINERALS.

Alum, *Alm.* Antimony Ores, *Ant.* Arsenical Minerals, *Ars.* Asbestus, *Asb.* Bismuth and Cobalt Ores, *B.C.* Borax, *Bx.* Chrome Ores, *Chr.* Copper Ores, *Cop.* Corundum, *Cor.* Gypsum, *Gyp.* Lead Ores, *Ld.* Magnesia Minerals, *Mag.* Manganese Ores, *Man.* Mica, *Mi.* Natron, *Nat.* Nitre, *Nit.* Ochres, *Ochr.* Phosphates, *Pho.* Platinum, *Plt.* Plumbago, *Plm.* Soapstone, *Sop.* Soda Salts, *Sod.* Sulphur, *Sul.* Tin Ores, *Tn.* Zinc Ores, *Znc.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
ANTIMONY ORES, *Ant.*	CHOTA NAGPUR— Dhadka (Manbhum) .	Man. III. 164 .	LD. .	Associated with lead ores.
	Hisatu (Hazaribagh) .	" " .	G. LD.	
ASBESTUS, *Asb.*	CHOTA NAGPUR— Manbhum Dist. .	Man. III. 519 .	...	No abundant source known.
BISMUTH & COBALT ORES, *B.C.*	CHOTA NAGPUR— Singbhum Dist. .	Man. III. 163; Rec. III. 97.	COP. .	Traces of bismuth from copper ores.
COPPER ORES, *Cop.*	BHAGULPUR— Bairuki . .	Man. III. 244; IV. 25.	...	Deogarh Copper Mines Company.
	Deogarh . .	Man. III. 244; IV. 25.	LD.	
	BURDWAN— Bodh Bandh . .	Man. III. 244. .		
	CHOTA NAGPUR— Baragunda . .	Man. III. 254 .	LD. .	The Bengal Baragunda Copper Company, for the year ending December 1888, turned out 218 tons of refined copper.
	Chaibassa . .		G. SLT. SND.	
	Daltonganj . .	Man. III. 256 .	C.	
	Kalianpur (Manbhum)	" 247.		
	Kasianuan .	" 256.		
	Landu (Singhbhum) .	" 249; IV. 5; Rec. III. 89.	...	Traces of native metallic copper.
	Purda (Manbhum) .	Man. III. 246 .	...	Ancient copper mine.
	Singhbhum . .	" 247 .	...	Numerous localities for a distance of 76 miles, between Lopso on the frontiers of Lohardaga, and Kamerara on those of Midnapur.

BENGAL—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COPPER ORES, *Cop.*—*contd.*	RAJSHAYE—			
	Buxa (Chel R.) .	Man. III. 276; Mem. XI. 79.	...	Worked 1871-72.
	Kalingpung . .	Man. III. 275; Mem. XI. 76.		
	Mahanadi . . .	Man. III. 275; Mem. XI. 78.		
	Mangphu . .	Man. III. 275; Mem. XI. 76.	...	Said to be the only mine worked at present in Darjeeling territory.
	Pashok . .	Man. III. 275; Mem. XI. 75.		
	Rangbong . .	Man. III. 275; Mem. XI. 75.		
	Rani Hat . .	Man. III. 274; Mem. XI. 72.	...	Traces. One set of mines worked in 1873.
	Re Ung . .	Man. III. 275; Mem. XI. 76.		
	Sampthar . .	Man. III. 275; Mem. XI. 78.		
CORUNDUM, *Cor.*	BHAGULPUR—			
	Jamui Hills? (Monghyr) . .	Stat. Acct. XV. 31	Mi.	
LEAD ORES, *Ld.*	BHAGULPUR—			
	Bairuki . .	Man. III. 287 .	Cop. .	Deogarh Copper Mines.
	Chakai Hills . .	" 290 .	Mi. .	Rumours of lead ores.
	Dudijor . .	" 289 .		
	Gonora . .	" " .		
	Gouripur or Phaga .	" 288 .		
	Karabank . .	" 289 .		
	Karda . .	" " .		
	Kajurea . .	" " .		
	Kharakpur Hills? .	" 290 .	I. Slt. Snd. .	Rumours of lead ores.
	Khurikhar . .	" 289		
	Panch Pahar or Akasi	" 287 .	...	Poor prospect.
	Sankera Hills . .	" 286		
	Turee Pahar or Tiur .	" 287		Silver lead ores.
	CHOTA NAGPUR—			
	Baragunda . .	Man. III. 292 .	Cop. .	Baragunda Copper Mines.
	Barikhap (Lohardaga)	" 294 .		
	Barhamasia . .	" 292 .	...	No silver reported.
	Bhelounda (Sirguja State) . .	" 294 .		
	Chiraikhund (Sirguja State.)	" 295 .	...	Abandoned lead mine.

BENGAL—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
LEAD ORES —*contd.*	CHOTA NAGPUR—*contd.*			
	Dhadkha (Manbhum)	Man. III. 290	ANT.	Fine argentiferous ore.
	Hisatu	" 293	G., ANT.	
	Khasmi	" 292.		
	Mahabagh	" 291	COP., LIM., ZNC,	Argentiferous galena; good.
	Mahandadi	" 29.		
	Mukundganj	" "		
	Nawada	" "		
	Parseya	" 293.		
	Sili (Lohardaga)	" 294.		
MANGANESE ORES, *Man.*	CHOTA NAGPUR—			
	Chaibassa	Man. III. 328; Mem. XVIII. Pt. 2. 87.	G. COP. SLTE. SND.	Manganiferous limonite; abundant.
MICA, *Mi.* (Erroneously called Talc: Mica is an elastic mineral; Talc is only flexible and seldom in plates.)	BHAGULPUR—			
	Chakai Hills	Man. III	LD.	
	Jamui	...	? COR.	
	Jamtara	Man. III. 527.		
	CHOTA NAGPUR—			
	Bhooria.			
	Dhanwi	Man. III. 525	...	1863; 10,000 maunds were exported, value Rs. 30,000.
	Dhab or Dhub	" 526; Rec. VII. 41.		
	Dhobapat.			
	Dumchash.			
	Gawan.			
	Gumji	Man. IV. 96; Rec. VII. 41		
	Kakariar.			
	Kuderma	Man. III 526		In 1843, 9 Mica mines; annual rent Rs. 113-10.
	Quadrumma	" 525.		
	Ghingho.			
	PATNA—			
	Chutkari	...	GRT.	Usually called Gya mines.
	Dabour			
	Rajaoli	Man. III. 527.		
OCHRES, *Och.*	BHAGULPUR—			
	Kharakpur Hills	Man. III. 417.		
	Rajmahal	" "		
PHOSPHATES, *Pho.*	CHOTA NAGPUR—			
	Smiratari	Man. III. 455; Rec. VII. 43.	...	Apatite, crystals, rare.

BENGAL—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
PHOSPHATES, *Pho.—contd.*	CHOTA NAGPUR—*contd.* Tendwa Nadi.			
	ORISSA— Ramidi . . .	Rec. VII. 43. Man. IV. 131; Mem. I. 37.	...	Apatite, crystals, rare.
PLATINUM, *Plt.*	CHOTA NAGPUR— Guram R. (Dhadka, Manbhum).	Man. IV, 3; Rec. XV, 55.	...	Traces.
	Landu (Chaibassa) .	Man. IV. 3; Rec. XV. 55.		
	ORISSA— Brahmini R. . .	Man. IV. 3; Rec. XV. 55.		
PLUMBAGO, *Plmb.*	CHOTA NAGPUR— Hutar (Koel R.) Loharduga.	Man. III. 53 . .	C. . .	Trace in gneiss.
SOAP-STONE, *Sop.* (Includes Steatite, Pot-stone, Talc. (not Mica), Bulpum).	CHOTA NAGPUR— Aranga . . Bandgaom . . Barahatu . . Bogra . . Chaibassa . . Ellora . . Gendra . . Gopalpur . . Jabla . . Jogidih . . Khurbunni . . Moisara . . Mutgoda . . Pardih . . Pokarhattu . . Punsa . . Sarusbad . . Semna . .	Man. III. 442; Mem. XVIII. 111—148.	...	All these are rather potstones, a coarse form of soapstone or steatite.
	ORISSA— Nilgiri Hill . .	Man. III. 441.		
	PATNA— Pathalkoti . .	Man. III. 441; Stat. Acct. XIII. 26.	...	Dark blue or black.
SODA SALTS, *Sod.*	RAJSHAHYE DIV.— Darjiling Terai .	Man. III. 495; Mem. XI. 90. .	...	Sodium sulphate from salt licks along out-crop of Damuda rocks, foot of Darjiling Hills.

BENGAL—*continued.*

MISCELLANEOUS MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
SODA SALTS, *Sod.*—*contd.*	PATNA DIVISION— Behar			Patna *Khari*; sodium carbonate, produced artificially from soil efflorescence of sodium sulphate, a form of *reh.*
TIN ORES. *Tn.*	CHOTA NAGPUR— Nurgo or Nurunga .	Man. III. 314; Rec. VII. 35.	I . .	Grains of tinstone in gneiss.
	Phira . .	Man. III. 315; Rec. VII. 35.		
	Simratari . .	Man. III. 315; Rec. VII. 35.		Traces.
ZINC ORES *Znc.*	BHAGULPUR— Bairuki (Santhal Parg.)	Man. IV. 18, 25 .	COP. LD. .	Deogarh Copper Mines.

GEM, STONES.

Amber, *Amb.* Beryl, *Brl.* Diamond, *D.* Garnet, *Gar.* Jade, Jadeite, *Jd.* Quartz, *Q.* Rubellite, *Rbl.* Ruby, *R.* Sapphire, *S.* Spinel, *Spl.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
BERYL, *Brl.*	CHOTA NAGPUR— Tendwaha R. (S. of Mahabar Hill, Hazaribagh).	Man. III. 521; Rec. VII. 43.	...	Small crystals, yellow.
	ORISSA— Ramidi . . Ungul . .	Mem. I. 56; Man. IV. 87.	...	Also Chrysoberyl.
DIAMOND, *D.*	CHOTA NAGPUR— Koel R. ? . .	Man. III. 24 .	...	Apparently fabulous.
	Sunk R. ?			
QUARTZ &c., *Q.*	BHAGULPUR— Barhait (Panch Pahar)	Man. III. 505 .	TRP. . .	Agates, quartz crystals, smoky quartz, also carnelian.
(Includes Rock crystal and the various forms of Quartz: as Agate, Amethyst, Bloodstone, Chalcedony, Chert, Flint, Jasper, Onyx, Opal. &c.)	BURDWAN— Bankura . .	Man. IV. 68 .	...	Rose quartz.
	CHOTA NAGPUR— Hazaribagh . .	Man. IV. 68 .	...	Rose quartz.
	Palamow . .	Man. III. 505 .	...	Agates.
	Singhbhum . .	" " .	...	Banded jaspers.

BENGAL—*continued.*

QUARRY STONES.

Clays, *Cly.* Granite, gneiss, &c., *Grt.* Laterite, *Lte.* Limestone, Marbles, Kunkar, *Lim.* Sandstone, *Snd.* Slate, *Slt.* Trap, Basalt, &c., *Trp.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
CLAYS, *Cly.*	BHAGULPUR—			
	Colgong, Lohandia, Monghyr, Patharghata, Rajmahal Hills	Man. III. 565	...	Pottery clays.
	BURDWAN—			
	Bankura	Man. III. 566	...	White lithomarge from lateritic deposits, 12 miles N. E.
	Monad	" 564	...	Tenacious loam, used as glaze or varnish.
	Raniganj	" 565	C.	Coal-measure clays; also fire clays. Messrs. Burn & Co.'s Pottery Works.
	CHOTA NAGPUR—			
	Karharbari	Man. III. 569	C.	Fire clays in coal measures.
	PRESIDENCY—			
	Akra	Man. III. 569	...	Brick factory. Alluvial clays.
	Kulna	" 564	...	Siliceous and ochreous earth, used for glaze or varnish.
GRANITE, &c., *Grt.* (Includes all fairly compact crystalline rocks; as gneisses of all kinds, generally of grey greenish or flesh colors. Not compact massive black or dark green rocks such as Basalt, Trap, &c.)	BHAGALPUR—			
	Colgong	Man. III. 536	...	Small hills of piled masses of compact grey granite quarried in old times.
	CHUTIA NAGPUR	......	...	Gneisses and granites common; but have not been much used.
	ORISSA—			
	Niltigarh Hill (Ultee Pargana).	Man. III. 536	...	Garnetiferous gneiss.

BENGAL—*continued.*

QUARRY STONES—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
LATERITE, *Lte.*	BHAGULPUR—			
	Kharakpur Hills	Man. III. 550	I. SLT.	
	Rajmahal	" "	TRP.	
	BURDWAN—			
	Bankura,			
	Mahommed Bazar	......	I.	
	Midnapur	Man. III. 550.		
	DACCA—			
	Madapur Jungle ?			
	ORISSA	Man. III. 550	...	Largely used in connection with irrigation works.
LIMESTONE, &c., *Lim.* (Includes: Marbles of different kinds, calcareous flag-stones, Travertine, 'Kunkar,' or 'Ghutin.' And, for convenience, serpentines and alabaster.)	...	......	...	Kunkar is generally distributed, even in the alluvium: mostly used for lime or road material, very seldom as a building material.
	BURDWAN—			
	Barakar	......	C. I.	Kunkar.
	Jamwan	Man. III. 458	...	Limestone.
	Ramlallpur	" "	...	Dolomitic lime-stone.
	Raniganj	......	C.	Kunkar.
	CHOTA NAGPUR—			
	Deredag (Lohardaga)	Man. III. 458; Mem. XV. 32. 125	...	Very considerable deposit, in calcareous gneisses.
	Hansapathar	Man. III. 458	...	Crystalline lime-stone.
	Mahabagh	" 459; Rec. VII. 34.	LD.	Ditto.
	Pachit Hill	Man. III. 458.	SND.	Limestone associated with sand-stones. N.-W. corner of hill.
	Purda	" "	COP.	Crystalline dolomite.
	Satbarwah	" 459	...	Limestone, abundant, but not very pure.
	Singbhum	" 447; Mem. XVIII. Part 2.	...	Serpentines have been found.
SAND-STONE, *Snd.*	BHAGULPUR—			
	Kharakpur Hills	......	...	Massive beds of quartzite or altered sandstone.
	Rajmahal Hills	Man. III. 547	...	Sandstones and flags.

BENGAL—*concluded.*

QUARRY STONES—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
SAND-STONE, *Snd.*—*contd* (Includes any sandy rock used for building, even calcareous sandstones. Flags; also quartzites which are only indurated sandstones. Pebbly rocks.	BHAGULPUR—*contd.* BURDWAN— Barakar	Man. III. 546	...	Numerous sandstones of every degree of durability and consistence. Numerous quarries.
	CHOTA NAGPUR— Giridih	......	...	Sandstones of all kinds.
	Hazaribagh Karharbari Ranchi	Man. III. 547.		
	Susunia Hill	„ 549	...	Quartzite, altered sandstone. Burdwan Paving Stone Co.
	ORISSA— Cuttack Kundagiri	Man.III. 547; Jour. As. Soc., Bengal, XI. 836; Rec. V. 59.		
SLATE, *Slt.* (Includes flags, though these are cleaved like slates.)	BHAGULPUR— Kharakpur Hills	Man. III. 552	...	Coarsely cleaved, coarse clay slates; not proper slates, but an approach to the material of English commerce.
	CHOTA NAGPUR— Chaibassa	Man. III. 553	...	Some of these coarse clay slates are finer and better than those of Kharakpur.
	Manbhum	„ „	...	Generally distributed; but poor, and have never been utilized.
	Singbhum	„ „	...	
TRAP, *Trp.*	BHAGULPUR— Rajmahal Hills	Man. III. 538, 539	...	Basaltic trap flows and sheets.
(Includes Basalt, whinstone, and other compact massive dark colored rocks).	BURDWAN— Raniganj Coal-field	Man. III. 538, 539	...	Dykes of greenstone.
	CHOTA NAGPUR— Dalma Hill	Man. III. 538, 539		
	Kuchung	„ „	...	Dykes.
	Mainpat	„ „	...	Basalt, Deccan Trap Series.
	Pubbia	„ „		
	Rajabasa Hill	„ „		
	ORISSA—			

BOMBAY.

IMPORTANT MINERALS.

Coal, *C.* Iron Ores, *I.* Gold, *G.* Petroleum, *Oil.* Salt, *Sal.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL, *C.* .	SIND DIVISION—			
	Lainyan . .	Man. III. 96; Mem. VI. 13; XVII. 192.	I. . .	No true coal, but only lignite, according to Mr. Blanford. Not without promise.
IRON ORES, *I.*	NORTHERN DIVISION—			
	Ahmedabad Collectorate—			
	Gogha . .	Bomb. Gazetteer, VI. 11.		
	Kaira Collectorate—			
	Kapadvanj . .	Bomb. Gazetteer, III. 15.		
	Panch Mehals Collectorate—			
	Godra Village (Palanpur).	Bomb. Gazetteer, III. 197.		
	Jambughora . .			
	Surajpur . .			
	Rewa Kantha—			
	Bhelod . .	Sel. from Rec., Bomb. Govt., XXIII. 109; Mem. VI. 578; Bomb. Gazetteer, VI. 11.		
	Jambughora . .			
	Sunodra . .			
	Tadkesar . .			
	Surat Collectorate—			
	Balsar . . .	Man. III. 399; Bomb. Gazetteer, II, 38.		
	Bodham . .			
	Pardi. . . .			
	Katch Agency—			
	Bhachan . .	Trans. Geol. Soc., Lond., V. 2nd Series, 293; Mem. IX. 87; Bomb. Gazetteer, V. 19; Sel. from Rec., Bomb. Govt., XV. 72.		
	Dudhai . .			
	Kaura . . .			
	Lunva . . .			
	Kattywar Agency—			
	Ranawao . .	Sel. from Rec., Bomb. Govt. XXXVII. 465.		
	Ranpur . .			
	CENTRAL DIVISION—			
	Sattara Collectorate.	Man. III. 398; Madras Jour. Lit. and Sci., VI. 364.	LTE.	

BOMBAY—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
IRON ORES, *I.—contd.*	SOUTHERN DIVISION— *Ratnagiri Collectorate*	Man. III. 398; Jour. Bomb. Branch, Roy. As. Soc., I. 139 and 436.	LTE.	
	Kholapore Agency— Cunala . . Kohlapur . . Vishalgarh . .	Sel. from Rec., Bomb. Govt., VIII. 34.	LTE.	
	Sawantwari Agency .	Sel. from Rec., Bomb. Govt., X. 44.		
	SIND DIVISION— Bandh Vera (east of) Jhirak (W. and S. W. of). Kotri (N.W. of) . Lainyan . . . Laki Range (base of).	Mem., XVII. 193.		
GOLD, *G.* .	NORTHERN DIVISION— *Kattywar Agency—* Aji . . . Sourekha . .	Sel. from Rec., Bomb. Govt., XXXVIII. 36.		
	SOUTHERN DIVISION— *Belgaum Collectorate*— Belowuddi . . Byh Hongul . . Chikota . . Murkombi . . Murgur. . .	Man. III. 207.	Q.	
	Kaladgi— Guludegud . .	Man. III. 207.		
	Dharwar Collectorate— Chik Mulgund . Dambal (or Damul) Dhoni . . . Harti (Hurtee) . Surtur . . .	Madras Jour., Lit. and Sci., XI. 44; Jour. Roy. As. Soc. VII. 205; Jour. As. Soc., Beng., XIV. 291; Trans. Bomb. Geog. Soc., XI. 1; Rec., VIII. 133; Mem., XII. 259; Balfour's Cyclopædia, Art. Gold.	...	Quartz reefs.

BOMBAY—*continued.*

IMPORTANT MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
PETROLEUM, *Oil.*	NORTHERN DIVISION— *Cutch Agency* . .	Mem. IX. 89 .	...	No real oil, but only bituminous lumps.
SALT, *Sal.*	......	No reliable information as yet.		

MISCELLANEOUS MINERALS.

Alum, *Alm.* Antimony Ores, *Ant.* Arsenical Minerals, *Ars.* Asbestus, *Asb.* Bismuth and Cobalt Ores, *B.C.* Borax, *Bx.* Chrome Ores, *Chr.* Copper Ores, *Cop.* Corundum, *Cor.* Gypsum, *Gyp.* Lead Ores, *Ld.* Magnesia Minerals, *Mag.* Manganese Ores, *Man.* Mica, *Mi.* Natron, *Nat.* Nitre, *Nit.* Ochres, *Ochr.* Phosphates, *Pho.* Platinum, *Plt.* Plumbago, *Plm.* Soapstone, *Sop.* Soda Salts, *Sod.* Sulphur, *Sul.* Tin Ores, *Tn.* Zinc Ores, *Znc.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
ALUM, *Alm.*	NORTHERN DIVISION— *Cutch Agency*— Mhurr or Madh .	Man. III. 432; Mem. XI 88.		
	SIND DIVISION— Suleman range, flanks of.	Mem. XVII. 195; Man. III. 434.	...	Probable.
BORAX, *Bx.*	NORTHERN DIVISION— *Kattywar Agency* .	Man. III. 498.		
COPPER ORES, *Cop.*	SOUTHERN DIVISION— *Dharwar Collectorate* Kappatgode range .	Jour. R. As. Soc. VII. 150; Madras Jour. Lit. and Sci., XI. 42. Rec. VII. 140.		
GYPSUM, *Gyp.*	NORTHERN DIVISION— *Bombay Collectorate* .	Man. III. 451 .	...	As selenite; small production.
	Cutch Agency— Chitrore (near) . Lukput . . . Mhurr (W. of) Oomirsir (E. & N.-E. of). On the Runn, east of Adeysur.	Mem. IX. 90 .	...	Occurs in large quantities.
	Kattywar Agency .	Man. III. 451; Mem. XXI. 62	...	As selenite; small production.

BOMBAY—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals	REMARKS.
GYPSUM. *Gyp.—contd.*	SIND DIVISION— Kirthar range .	Mem. XVII. 195; Trans. Bom. Geol. Soc. X. 229.		
LEAD ORES, *Ld.*	NORTHERN DIVISION— *Panch Mehals Collectorate.* Jubhan and Khandelao Lake.	 Bomb. Gazetteer, III. 197.		
MANGANESE ORES, *Man.*	SOUTHERN DIVISION— *Dharwar Collectorate.* Bhimgarh . . Wodoorti (in the Kappatgode range).	 Mem. XII. 259. Jour. R. As. Soc. VII. 212; Madras Jour. Lit. & Sci. XI. 44.		
MICA, *Mi.* (Erroneously called Talc: Mica is an elastic mineral; Talc is only flexible, and seldom in plates.)	NORTHERN DIVISION— *Rewakantha Agency*— Jambughora . .	 Sel. from Rec., Bomb. Govt. XXIII. 101.		
NITRE, *Nit.*	NORTHERN DIVISION— *Ahmedabad Collectorate.*	Man. III. 501 .	...	Manufacture now almost extinct.
SOAPSTONE, *Sop.* (Includes Steatite, Potstone, Talc (not mica), Bulpum).	SOUTHERN DIVISION— *Dharwar Collectorate* *Ratnagiri Collectorate*	Madras Jour. Lit. & Sci. IV. 462; Jour. As. Soc. Beng., XIV. 291; Mem. XII. 258. Jour. Bomb. Branch R. As. Soc. I. 144.		
SULPHUR, *Sul.*	SIND DIVISION— *Karachi Collectorate*— Ghizri Bandar .	 Jour. As. Soc. Beng. XII. 835.		
TIN ORES, *Tn.*	SOUTHERN DIVISION— *Dharwar Collectorate*— Dambal Hills . Gujrat. Jambughora . .	 Rec. VII. 140 . Man. III. 315.	 G. GRT. .	 Trace.

BOMBAY—*continued.*

GEM STONES, &c.

Amber, *Amb.* Beryl, *Brl.* Diamond, *D.* Garnet, *Gar.* Jade and Jadeite, *Jd.* Quartz, *Q.* Rubellite, *Rbl.* Ruby, *R.* Sapphire, *S.* Spinel, *Spl.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
QUARTZ, *Q.*	NORTHERN DIVISION—			
(Includes Rock Crystal and the various forms of Quartz: as Agate, Amethyst, Bloodstone, Chalcedony, Chert, Flint, Jasper, Onyx, Opal, &c.)	*Ahmedabad Collectorate*—			
	Ranpur . .	J. M. Campbell; Bomb. Gazetteer; Man. III. 508.	...	Cambay Stones carnelians, agates &c.
	Kaira Collectorate—			
	Kapadvanj.	Do. do.		
	The Manjam.			
	Cutch Agency—			
	Dhokavada . .	Do. do.		
	Guzerat . .	Bomb. Govt. Sel. XVI. 49.		
	Kattywar Agency—			
	Nr. Mahmedpur .	J. M. Campbell; Bomb. Gazetteer; Man. III. 508.		
	Bud Kotra.			
	Tankara . .	J. M. Campbell; Bomb. Gazetteer; Man. III. 509.		
	Bhag Hill . .	Do. do.		
	Rewa Kantha Agency—			
	Ratanpur . .	Mem. VI. 381; Bom. Gazetteer, VI. 205.		
	Malwa State—			
	Ujein . .	Man. III. 514.		

QUARRY STONES.

Clays, *Cly.* Granite, Gneiss, &c., *Grt.* Laterite, *Lte.* Limestone, Marble, Kunkar, &c., *Lim.* Sandstone, *Snd.* Slate, *Slt.* Trap, Basalt, &c., *Trp.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
CLAYS, *Cly.*	SIND DIVISION—			
	Fatta . .	Man. III. 566; Birdwood: Industrial Arts of India.	...	For production of glazed pottery.
	Hala . .			
	Hyderabad.			
	Jerruck.			
	Bulri . .	Do. do. . .	...	Production of encaustic tiles.
	Saidpur . .			

BOMBAY—*continued.*

QUARRY STONES—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
GRANITE, *Grt.* (Includes all fairly compact crystalline rocks; as gneisses of all kinds, generally of grey greenish or flesh colors. Not compact massive black or dark green rocks such as Basalt, Trap, &c.)	DIVISION ?— Goomlee . .	Professional Papers on Indian Engineering, VI. 137, 1869, Roorkee.	...	Syenite obtainable here.
	CENTRAL DIVISION— *Ahmednagar Collectorate* . . *Khandesh Collectorate* . . *Poona Collectorate* . *Sholapur Collectorate*	Mem. VI. 362,363	...	Distributed.
LATERITE, *Lte.*	SOUTHERN DIVISION— *Belgaum Collectorate.*— Dharwar . . Kaunia . . Ratnagiri . .	Mem. XII. 267; Rec. IV. 44.	...	Distributed; Konkan laterite.
LIMESTONE *Lim.* (Includes most marbles of different kinds, calcareous flagstones, kunkar, or ghutin, travertine: also, for convenience, serpentines and alabaster.)	NORTHERN DIVISION— Western extremity of Narbada Valley.	Mem. VI. 216 .	...	Limestones, cretaceous and nummulitic.
	Panch Mehals Collectorate— Dohad . .	Man. III. 465.		
	Jambughora . .	" "		
	Pali Station . .	Bomb. Gazetteer, III. 197.	...	Kunkar.
	Surat Collectorate— Turkesar . .	Man. III. 465.	-	
	Cutch Agency— Nr. Hybbye on the Juria Hills. Kala Mountains (in the Putchum). The Lodge and Jarun Range. Raimulru (Nr. Kaora).	Mem. IX. 90; Man. III. 466.		
	SOUTHERN DIVISION— *Dharwar Collectorate*— Dhoni (N. & N. W.) of).	Rec. VII. 134; Mem. XII. 262—264.	...	Would also yield lime.
	SIND DIVISION— Jhirak . . Karachi.	Mem. XVII. 194.	C. I. GYP. ALM.	

BOMBAY—*concluded.*

QUARRY STONES—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
LIMESTONE *Lim.—contd.*	SIND DIVISION—*contd.*			
	Guzerat—			
	Gir Hills.	Man. III. 465.		
	Porebunder.			
	? DIVISION—			
	Lakaree	Prof. Papers on Indian Engineering, VI. 1869, Roorkee.		
	Gooneaser .			
SAND-STONES, *Snd.* (Includes any sandy rock used for building, even calcareous sandstones. Flags. Also quartzites which are only indurated sandstones. Pebbly rocks)	NORTHERN DIVISION—			
	Cutch Agency . .	Mem. IX. 93.		
	Kattiwar Agency .	Mem. XXI. 62.		
	Western Sind . .	Mem. XVII. 194.		
SLATE, *Slt.*	SOUTHERN DIVISION—			
	Belgaum . .	Mem. XII. 262.		
(Includes flags; though these are cleaved like slates.)	? NORTHERN DIVISION ·			
	N. E. of Baroda (between Surajpur and Jambughora).	Mem. VI. 217.		
TRAP, &c. *Trp.* (Includes basalt, whinstone, and other compact massive dark colored rocks.)	Bombay Island .	Mem. V. 14.		
	Bhuj (Cutch) . .	Prof. Papers on Indian Engineering (Roorkee), VI, 1869, 134.	LIM. . .	Basaltic.
	Ballacherry (Kattywar)	Do. do. 135		
	Behree Bunder (Kattywar)			
	Nowa Nugger (Kattywar)			
	Additiana . .	Do. do. 137.		Universal over the Deccan. Always good building stones.
	Chumardee Hills .	Do. do. 140.		
	Bhownugger . .	Do. do. 141.		
	Bhugwarra . .	Do. do. 142.		
	Damaun . .			
	Doongree . .			
	Kookranee . .			
	Neela Doongree .	Do. do. 143.	LTE.	
	Daravee . .	Do. do. 143.		
	Bandora . .	Do, do. 144.		

BURMA.

IMPORTANT MINERALS.

Coal, *C.* Iron Ores, *I.* Gold, *G.* Petroleum, *Oil.* Salt, *Sal.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL, *C.*	ARAKAN DIVISION— *Kyaukpyu District—* Ramri; Cheduba, &c.	Rec. XI. 209	OIL, LIM.	
	IRRAWADDY DIVISION— *Hensada District—* Mokhoung; Poosoongyee; Kywaising	Rec. XV. 178	OIL.	
	PEGU DIVISION— *Thayetmyo District—* Thayetmyo	Sel. Rec. Gov. Ind., X. 99; Mem. X. 295: Rec. XVIII. 150.	LIM. OIL	No good. Has been unsuccessfully worked.
	TENASSERIM DIVISION— Great Tenasserim; Little " ; Lenya R.	Sel. Rec. Gov. Ind., X. 31.		
	MERGUI— Nr. Thuggoo	Sel. Rec. Gov. Ind., X. 852; J. A. S. B., XVI. 1, 369.	I. LIM.	Impure graphite.
	UPPER BURMA.			
	NORTHERN DIVISION— Thingadaw	Geol. Papers on Bur., 318; Dr. Anderson's W. Yunnan, 198-9; Bredemeyer, M. S. Report; Ind. Econ., V. 14.		
	Shwaygoo, below Bhamo.	Ind. Econ. V. 14.		
	SOUTHERN DIVISION— *Yaw District—* Yaignaw E. of Nat-taik.	Ind. Econ., V. 14.		
	EASTERN DIVISION— *Meiktila and Shan Hills—* Panlaung	Rec. XX. 177; Ind. Econ., V. 14.	...	Probably not workable.
	Legaung Nr. Singulebyin.	Rec. XX. 188.	...	No prospect of successful working.
	Ngw, nr. Puehla	" 189.		Ditto ditto.

BURMA—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL, *C*—*contd.*	CENTRAL DIVISION—*Chindwin*— Kalewa, and northwards beyond Yu R.	Rec. XX. 170 .	...	Fairly promising.
IRON ORES, *I.*	PEGU DIVISION— Eastern Prome District	Mem. X. 65, 343	...	Hydrated peroxide, in fossil wood group; magnetic ore in the metamorphics and specular in the schists.
	TENASSERIM DIVISION— Tavoy . .	Helfer. Rep. on ye Tavoy, &c., 29; Rec. VI. 91; (Geol. Papers, 407); J. R. A. S., III. 49; J. A. S. B., XIII. 236, 238	LIM., TN., G., COP., PLT.	Magnetic ore in many places.
	Mergui . .	J. A. S. B., XIII. 237, 239; Geol. Papers Bur. 466.	LIM. C. TN.	Brown hematite.
	UPPER BURMA— Poppadoung . .	Geol. Papers Bur. 335; J. A. S. B., XXXI, 219; (Geol. Papers, Bur. 341.)	TRP. .	Peroxide of iron in fossil wood group.
	Shwebo . . .	Geol. Papers, 335.	NIT. .	Occurs at Macdoo some way north of Shwebo.
	Shan States . .	Do. do. 335; Ind. Econ. V. 14.	COP. .	Large quantities of hematite.
	Sagaing . .	Ind. Econ. V. 14.		
GOLD, *G.* .	PEGU DIVISION— Shwegyeng . . Prome . .	Mem. X. 343 . .	OIL.	
	TENASSERIM DIVISION— Shwegyeng (Sittang)	Mem. I. 94.; Adm. Rep. B. B., 1863-64, 56; Adm. Rep. B. B., 1866-67, 96; Adm. Rep. B. B., 1868-69, 107; B. B. Gazette, II. (1879). 649; Geol. Papers, Bur. 463.		
	Henzai R. . .	Man. III. 229.	C.	
	Tavoy . . .	" "	TN. LIM. MAN., PLT. COP.	
	Tenasserim . .	Helfer's 2nd Rep. Ye, &c., 34.	TN.	

BURMA—*continued.*

IMPORTANT MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
GOLD—*contd.*	UPPER BURMA—			
	Hunkong Valley .	J. A. S. B., VI. 270	SAL. AMB.	
	Chindwin (Kani) .	J. A. S. B., I. 16.	PLT.	
	Upper Irrawaddy .	Geol. Papers, Bur., 332; J. A. S. B., I. 17.	PLT.	Bhamo. Bhamo and Thingadaw.
	Upper Irrawaddy .	Anders., Yunnan, 200, 201.	...	
	Mogaung . .	Anders., Yunnan, 63.		
	Meza Valley . .	Rec. XIX. 268 (Chem. News, LIV. 278).		
	Shan States (N. E. of Mandalay)	Ind. Econ. V. 14.		
	S. E. of Mandalay at Thayetpein-yua.	" "		
	Yaw country.	" "		
	Taunglebyin . .	Rec. XX. 194.		
PETRO-LEUM, *Oil.*	ARAKAN DIVISION—			
	Ramri, Cheduba, Baronga } &c. .	Rec. XI. 207. .	C. LIM.	
	IRRAWADDY DIVISION— *Henzada District*—			
	Yaynantoung .	Rec. XV. 180 .	C.	
	PEGU DIVISION—			
	Thayetmyo . .	Mem. X. 346; Rec. III. 72., V. 120; Rec. XVIII. 149.	LIM.	
	Prome . .	Ind. Econ. III. 191; Rec. V. 120.	G.	
	UPPER BURMA—			
	Pagan . .	Geol. Paper, Bur., 302.		
	Yenangchoung (Yenangyoung)=Tesingoung and Beme of Dr. Noetling.	As. Res. VI. 127; Geol. Paper, Bur., 296; R. Romanis' Report, 1884; Rec. XIX. 203; XXII. 75.	...	Present yield estimated at 2½ million gallons *per annum.*
SALT, *Sal.* .	Pegu . .	Rec. VI. 67.		
	UPPER BURMA—			
	Shimpagah (above Mandalay on W. bank of Irrawaddy).	Ind. Econ., V. 14.	...	Doubtful.

BURMA—*continued.*

MISCELLANEOUS MINERALS.

Alum, *Alm.* Antimony Ores, *Ant.* Arsenical Minerals, *Ars.* Asbestus, *Asb.* Bismuth and Cobalt Ores, *B.C.* Borax, *Bx.* Chrome Ores, *Chr.* Copper Ores, *Cop.* Corundum, *Cor.* Gypsum, *Gyp.* Lead Ores, *Ld.* Magnesia Minerals, *Mag.* Manganese Ores, *Man.* Mica, *Mi.* Natron, *Nat.* Nitre, *Nit.* Ochres, *Ochr.* Phosphates, *Pho.* Platinum, *Plt.* Plumbago, *Plm.* Soapstone, *Sop.* Soda Salts, *Sod.* Sulphur, *Sul.* Tin Ores, *Tn.* Zinc Ores, *Znc.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
ALUM, *Alm.*	TENASSERIM DIVISION— *Amherst District*—			
	Yonzalin	Adm. Rep. B. B., 1861, 39.	LD.	
	Tenasserim	Mason's Burma, 33.		
ANTIMONY, *Ant.*	TENASSERIM DIVISION—			
	Martaban	Rec. VI. 94; B. B. Gazetteer, I. (1880), 65; J. A. S. B., V. 272.		
	Moulmein District.—			
	Toungweyn range	Man. III. 167; Man. IV. 13, 62. Rec. XVIII, 151.		
	Tenasserim	Mason's Burma, 33.	...	About 40 miles below Mahtah at the forks.
	UPPER BURMA—			
	Shan Country, East of Ava.	J. A. S. B. III. 194.		
ARSENICAL MINERALS, *Ars.*	TENASSERIM DIVISION— *Amherst District*—			
	Yonzalin R.	Proc. A. S. B., 1870, 279; Man. IV, 14.		
	Upper Burma	Man. III. 162	...	Said to occur here.
BISMUTH, AND COBALT ORES, *B.C.*	TENASSERIM DIVISION—			
	Between Attaran and Moulmein Rivers.	Jour. of the Ind. Archip. III. 733; Man. IV. 13. Man. III. 163.	COP.	Bismuth. Said to occur in Burma with Antimony and Galena.
	Henzai	J. A. S. B., XXXIII, 524.	G.	Cobalt.

BURMA—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COPPER, *Cop.*	TENASSERIM DIVISION—			
	Yonzalin R. . .	Proc. A. S. B., 1870, 279; Man. IV. 14.		
.	Moulmein and Tavoy	Sel. Rec. Gov. Beng., VI, 27, 33.	LIM., TN., G., I., PLT.	
	Megathat R. . .	Geol. Pap., Bur., 454.		
	UPPER BURMA—			
	Shan States . .	Geol. Pap., Bur., 335; Ind. Econ. V. 14. Rec. XX. 194.		
	Sagaing . .	Ind. Econ. V. 14 .	I.	
CORUNDUM, *Cor.*	Ruby Mines . .	See Ruby . .	...	Occurs with the ruby.
GYPSUM, *Gyp.*	Tenasserim R. (lat. 13° 14'N.) .	Man. III. 454.		
LEAD ORES, *Ld.*	TENASSERIM DIVISION—			
	Martaban . .	Rec. VI. 93.		
	Teetalay and Teetameelay Hills, &c.	Geol. Pap. Bur., 446, *et seq.*		
	Moulmein . .	Rec. XVI. 203 .	CLY.	
	Maingay's Island .	Geol. Pap., Bur., 421, 438.		
	Onkarcan . .	Geol. Pap. Bur., 457.		
	Tha-pe-do near Yonzalin R.	Geol. Pap. Bur., 470.	ALM.	
	Taw-de-lo near Pen-ni-pecco.	Geol. Pap. Bur., 472.		
	Tavoy district . .	Adm. Rep. B. B., 1861-62, 39.		
	Houndraw R. . .	Jour. Ind. Archip., III. 736.		
	UPPER BURMA—			
	Shan States . .	Ind. Econ., V. 14; Rec. XX, 191. Sel. Rec. Gov. Ind., XLIX. 39. Geol. Pap. Bur., 334; J. A. S. B., I. 15.		

BURMA—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
MAGNESIA MINERALS, *Mag.*	Arakan . .	Man. II. 714. .	...	Seams of carbonate of magnesia, in serpentine.
MANGANESE ORES, *Man.*	TENASSERIM DIVISION—			
	Mergui District—			
	King's Island . .	Man. IV. 61.		
	Tavoy District .	" " 62 .	TN., LIM. G.	
	Yètagôn above Yembaing on Salween.	R. Romanis' Report on Minerals in Tenasserim, 1.		
	Tounghu . .	Mem. X. 267.		
NATRON, *Nat.*	Upper Burma . .	Mason's Burma, 2nd Ed., 14.		
NITRE, *Nit.*	UPPER BURMA—			
	Toungthoo Einlay .	Ind. Econ., V. 14.		
	Amarapura . .			
	Shimpagah . .		SAL.	
	Ong-ben-lay . .	Ind. Econ., V. 14.		
	Leen-gine . .			
	Sameet Koon . .			
	Pyagan . .			
	Aung-gyeen . .			
	Samoon gyee . .			
	Ooyun-galay . .			
	Shuaybo . .		I.	
	Satoung-ma . .			
	Salem-myo . .			
	Myo-tha . .			
	Tsit-kine . .			
	Aloon . .			
	Tee-ber-yeen . .			
	Myay-yeen . .			
	Shin-bin-oon-Eni .			
	Yua-shit-gyee . .			
	Enidine-yua (Kyauksay S.E.)			
	East of Pagan (Youngdaw Toung.)			
OCHRES, *Ochr.*	Tavoy R.			
	Kallioung . .	Mason's Burma, 42.		
	Great Tenasserim .	Man. III. 418.		
PLATINUM, *Plt.*	TENASSERIM DIVISION—			
	Tavoy . .	Sel. Rec. Gov., Beng., VI. 38; Geol. Pap, Bur., 370.	TN., LIM., I., G., MAN., COP.	

BURMA—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
PLATINUM, *Plt.*—*contd.*	UPPER BURMA— Mandalay District near Ava.	Glean. in Sc., III. 39; As. Res. XVIII. 279; Rec. VI. 95.	...	Doubtful.
	Chindwin . .	J. A. S. B., I. 16	G.	
	Bhamo . .	" " 17.		
	Meza Valley . .	Rec. XIX. 268.		
	Shan States . .	Ind. Econ., V. 14.		
PLUMBAGO, *Plm.*	TENASSERIM DIVISION— *Mergui District.*— Nr. Thuggoo .	J. A. S. B., X. 852; XVI. 1, 369.		
	UPPER BURMA— E. of Nattaik, near Myoketoke.	Ind. Econ., V. 14.		
	Sagyin Hills . .	Letter from Fin. Com., Burma, 9-11-88.	SPL., R., LIM.	
SOAP-STONE, *Sop.* (Includes steatite, pot-stone, talc (not mica) Bulpum).	ARAKAN— Minbu . . .	Rec. IV. 43; Mem. X. 336—352.		
	Upper Burma . .	Man. III. 445.		
SULPHUR, *Sul.*	UPPER BURMA— Mooda Myo N. .	Ind. Econ., V. 14.		
	Tsein Goon E. S. E.			
	Kyoukhoo, S. E. .			
	Bawzin, Shan States, S. E. (Bawzaing).	Rec. XX. 194; Ind. Econ., V. 14.	COP., LD.	
	Dybagen Myo, N. W.	Ind. Econ., V. 14.		
	Pagan Myo, west bank of Irrawaddy.			
	Toogthoo Einlay, E. S. E., Bhamo District.	" "		
TIN ORES, *Tn.*	TENASSERIM DIVISION— Amherst and Tavoy Districts.	Rec. VI, Helfer, 2nd Rep. on Ye Tavoy, &c., 29; Sel. Rec. Gov., Beng., VI. 21; J. R. A. S., III. 47.	MAN., G., PLT., COP.	

BURMA—*continued.*

MISCELLANEOUS MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
TIN ORES, *Tin—contd.*	TENASSERIM DIVISION —*contd.* Mergui District . .	Geol. Pap., Bur., 413, *et seq*; Glean. in Sc., I. 143; Helfer, 2nd Rep., Ye Tavoy, &c., 31; J. A. S. B., XI. 841; J. A. S. B., X. 846; Sel. Rec. Gov. Ind., X. 57 (Geol. Pap. Bur., 396); Adm. Rep., Bur., 1874-75; Adm. Rep., Bur., 1877-78; Rec. XXII, 188.	...	Being exploited.
	UPPER BURMA— Shan States . .	Ind. Econ., V. 14.		

GEM-STONES, &c.

Amber, *Amb.* Beryl, *Brl.* Diamond *D.* Garnet, *Gar.* Jade and Jadeite, *Jd.* Quartz, *Q.* Rubellite, *Rbl.* Ruby, *R.* Sapphire, *S.* Spinel, *Spl.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
AMBER, *Amb.*	UPPER BURMA— Payentoung (Meinkhun).	J. A. S. B., VI. 270; Griffith's Priv. Jour. 77; Anders. Yunnan, 65.		
JADE, JADEITE, *Jd.*	Mogaung . .	Anders. Yunnan, 66.		
RUBY, *R.*	Ruby Mines . .	J. A. S. B., II. 75 (Geol. Pap. Bur., 285; Geol. Pap. Bur., 336).	SPL.	
	Sagyin Hills . .	Bredemeyer, M. S.; Ind. Econ., V. 14.	SPL. PLM.	

BURMA—*continued.*

GEM-STONES, &c.—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
RUBELLITE, *Rbl.*	Upper Burma . .	Mason's Bur., 2nd ed., 14; Man. IV. 108.		
SPINEL, *Spl.*	Tenasserim . .	Sel. Rec. Gov. Beng., VI. 38.		
	Ruby Mines . .	See RUBY . .	R.	
	Sagyin Hills . .	Rep. by Dr. Nötling.	R., LIM., PLM.	

QUARRY STONES.

Clays, *Cly.* Granite, Gneiss, &c., *Grt.* Laterite, *Lte.* Limestone Marbles, Kunkar, *Lim.* Sandstone, *Snd.* Slate, *Slt.* Trap, Basalt, &c., *Trp.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
CLAYS, *Cly.*	Alluvial portions of the country especially Tenasserim.	Mem. X. 341; Brit. Bur. Gazette, I (1880), 65.		
	Maulmain . .	Cal. Jour. Nat. Hist., II. 596.	LD. . .	Fire clay.
GRANITE, &c., *Grt.* (Includes all fairly compact crystalline rocks; as gneisses of all kinds, generally of grey, greenish or flesh color, not compact massive black or dark green rocks, such as Basalt, Trap, &c.)				
LATERITE, *Lte.*	Pegu . .	Mem. X. 56.		
	Sittang . .	Mem. X. 56; Adm. Rep. 63-65, 56; Brit. Bur. Gazetteer, II (1879), 648		
LIME-STONE, &c., *Lim.*	ARAKAN—			
	Ramri, &c. . .	Rec. XI. 221.		
	S. of Sandoway .	Mem X. 345.		

BURMA—*concluded.*

QUARRY STONES—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
LIMESTONE, &c., *Lim.—contd.* (Includes most marbles of different kinds, calcareous flag-stones, kankar or ghu-in, travertine: also, for convenience, serpentines, and alabaster).	PEGU—			
	Along Arakan Range W. of Irrawaddy.	Mem. X. 344.		
	Bassein . .	" "		
	Thyetmyo . .	......	C., OIL.	
	TENASSERIM DIVN.—			
	Maulmain . .	Mason's Burma, 29.		
	Taungyin Valley .	Romanis' Rep. on Minerals. in Tenasserim, 4.		
	Tavoy . . Mergui . .	J. A. S. B., XII. 238-9; Rec. XXI. 29.	TN., MAN., PLT., I., C., COP.	Elephant Island, Mergui Archipelago.
	UPPER BURMA—			
	Sagyin Hills . .	Geol. Pap. Bur., 308.	SPL. R.	
	Bhamo . .	Anderson's Yunnan. 59, 213.		
SAND-STONES, *Snd.* (Includes any sandy rock used for building, even calcareous sandstones, flags; also quartzites which are only indurated, sandstones. Pebbly rocks).	ARAKAN COAST— Koranji Island nr. Nga-Tha-Mu.	Mem. X. 152.		
SLATE, *Slt.* (Includes flags, though these are cleaved, like slates.)	No information.			
TRAP, &c., *Trp.* (Includes basalt, whinstone, and other compact massive dark colored rocks. All volcanic rocks.)	East of Sittang and in Tenasserim.	Mason's Burma, 2nd ed., p. 4.	...	Not largely developed.

CENTRAL PROVINCES.

IMPORTANT MINERALS.

Coal, *C.* Iron Ores, *I.* Gold, *G.* Petroleum, *Oil.* Salt, *Sal.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL, *C.*	CHHATTISGARH DIVISION—			
	Bilaspur District—			
	Ghordewa	Rec. XX. 199	SND.	Borings, 5′ of good coal.
	Korba	Rec. III. 54; X, 198.	SND.	In great seam, 69, of shale and coal; 38′ of favourable part of seam assayed, poor.
	Sambalpur District—			
	Hingir	Rec. IV. 101—107; Rec. VIII. 102—121.	I., SND.	Poor.
	Raigarh	Rec. IV. 101—107; Rec. VIII. 102—121.	I., SND.	
	Tumidih (Raigarh)	Rec. XX. 194	...	Poor
	NAGPUR DIVISION—			
	Chanda District	Man. III. 92.		
	Akapur	Mem. XIII. 23	I., SND.	
	Akarjun	" "		
	Bandar	Mem. XIII. 145—154; Man. III. 92; Man. I. 226.	...	Borings, 3 seams; like Warora.
	Ghugus	Mem. XIII. 32, 34.	...	45 million tons available.
	Kanji	" 23.		
	Telwasa	" 30.		
	Warora	" 23	SND.	14 million tons available. Collieries, output for half-year ending June 1889, 136, 795 tons, from three pits.
	NARBADA DIVISION	Man. III. 90; Mem. II. 97, 267; Mem. X. 133, 188.		
	Beitul—			
	Shahpur or Beitul field.	Man. III. 92; Rec. VIII. 65, 71.	...	Promising.
	Tawa	Rec. I. 8; Rec. VIII. 69, 75; Mem. XXIV. 40.	...	70 square miles.
	Chhindwara—			
	Barkoi field	Mem. XXIV. 23	...	7 square miles; old pit fallen in.
	Gajundoh field	" 34	...	Very small.
	Harai field	" 33	...	Small and unimportant.

CENTRAL PROVINCES—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COAL, *C.*—*contd.*	NARBADA DIVISION—*contd.*			
	Hingladevi field .	Mem. XXIV. 35 .	...	Nearly 3 square miles.
	Kanhan field . .	" 37 .	...	12 square miles.
	Pench (Chhindwara field.)	Man. III. 92 .	...	Many seams of coal, some of fair quality.
	Sirgora field . .	Mem. XXIV. 20 .	SND. . .	Very small.
	Narsingpur—			
	Mohpani . .	Man. III. 91; Mem. II. 2; X. Rec. III; IV, 66; V, 109; VIII; XII. 95.	...	Narbada Coal and Iron Co.'s collieries. Output for 1888, 23,442 tons.
	UMARIA COAL FIELD . (S. Rewah). See CENTRAL INDIA AGENCY.	Rec. XV. 169; XVI. 118; XVII. 146; Mem. XXI. Part 3.	...	Worked by C. P. Government. Output for half year ending June 1889 52,059 tons. Belongs properly to Cl. I. Agency.
IRON ORES, *I.*	CHHATTISGARH—			
	Bilaspur District .	C. P. Gazetteer.		
	Raipur District .	Man. III. 383.		
	Daundi Lohara. .	Rec. XX. 168.	...	Hematite; rich and abundant.
	Gundai . .	Rec. XX. 168.	SND. . .	Red hematite.
	Khairagarh . .	Rec. XX. 168.	SLT. . .	Hematite, and lateritic ores.
	Nandgaon . .	Rec. XX. 168.	LIM. .	Lateritic ores.
	Thakurtola . .	Rec. XX. 168.	CLY. .	Ditto.
	Worarbund . .	Rec. XX. 168.	...	Ditto.
	Sambalpur District—			
	Kodaloi . .	Man. III. 382 .	...	Raigarh and Hingir Coal-fields.
	Kudderbuga . .	Man. III. Rec. X. 182.	...	Weathered magnetite.
	Rehrakol . .	Man. III, 381; C. P. Gazetteer, 224—249.		
	JABALBUR DIVISION—			
	Damoh . .	Man. III. 387 .	...	Unimportant; Bijawar formation.
	Jabalpur . .	C. P. Gazetteer; Rec. XVI. 96; Rec. XXI. 71.		
	Agaria . .	C. P. Gazetteer; Rec. XVI. 96; Rec. XXI. 71.	...	Ores abundant in this district, most important mines being at Ghogra and Jaoli.
	Bolia . .	C. P. Gazetteer; Rec. XVI. 96; Rec. XXI. 71.		
	Dalrora . .	C. P. Gazetteer; Rec. XVI. 96; Rec. XXI. 71.		
	Dubwara . .	C. P. Gazetteer; Rec. XVI. 96; Rec. XXI. 71.	...	
	Ghogra . .	Man. III. 384.		
	Gosalpur . .	Rec. XXI. 71 .	...	Manganiferous Hematites, lateritic ores.
	Jaoli . .	Man. III. 384.		
	Lameta . .	Ditto.		

CENTRAL PROVINCES—*continued.*

IMPORTANT MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
IRON ORES, *I.—contd.*	JABALPUR DIVISION—*contd.*			
	Mungela . .	Man. III. 384; Rec. XVI. 96.		
	Palle (Pullee) . .	Man. III. 384; Rec. XXI. 71.		
	Panagarh . .	Man. III. 384.		
	Simra . .	" "		
	Mandla—			
	Umerwani . .	Rep. on the Mandla Dist. by Capt. Pearson, 1860, 21.	TRP.	
	Ramgar . .			
	Mowai . .			
	Saugor . .	Man. III. 387 .	...	Bijawar formation.
	NAGPUR DIVISION—			
	Balaghat . .	Man. III. 383.		
	Bhandara . .	Man. III. 383.	...	Lateritic ores in good part.
	Chandpur . .	" "		
	Tirora . . .	" "		
	Pratapgarh . .	" "		
	Chanda—	Q. J. Geol. Soc., XI. Pt. II, p. 345.	...	Chanda district richest in iron ore, in the Wardha valley.
	Bhanapur . .	Cent. Prov. Administ. Rep., 1861-79.		
	Ogulpet . .	Supplement to Gazette of India, 1871, 1341.		
	Dewalgaon . .			
	Gunjwahi . .	Do. do. 1874, 1854 and 1847.		
	Lohara . .		...	Largest deposit at Lohara; cryst. hematite, with magnetic oxide.
	Menda . .	Do. do. 1875, 288.		
	Metapur . .	David Forbes, "Colliery Guardian," 13th Sept. 1873.		
	Pipalgaon . .		...	Cryst. hematite, with magnetic oxide.
		Mining Journal, 25th Dec. 1875.		
	Ratnapur . .	Public Works Dept. Proceedings for May 1876.	...	Brown iron ore.
	NARBADA DIVISION—			
	Hoshangabad . .	Mem. XXI. 64.		
	Nimar—			
	Chandgar . .	Man. III. 397.		
	Punassa . .			
	Narsingpur—			
	Omarpani or Tendukhera .	Man. III. 385 .	LIM. SND. .	Hæmatites in the Bijawar formation; deposit probably abundant.

CENTRAL PROVINCES—*continued.*

IMPORTANT MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
GOLD, *G.*	CHHATTISGARH—			
	Bilaspur—			
	Sonakhan	Calc. Jour. Nat. Hist., III. 292.	...	? Sands.
	Raipur—			
	Rajim (Rajoo)	Calc. Jour. Nat. Hist., III. 292.	...	? Sands.
	Sambalpur—			
	Jhunan	Man. III, 200	...	Sands; colony of gold-washers.
	Sambalpur (Mahanadi R.).	Man. III. 200; Jour. As. Soc., Beng., VIII. 1058.		
	Sonpur (and Tributaries of Mahanadi)	Rec. X. 190.		
	Tahud (Ebe R.)	Man. III. 200; Rec. X, 191.	...	Sands; gold-washers.
	JABALPUR DIVISION—			
	Damoh	Man. III. 203.		
	Jabalpur	" "		
	Saugor	" "		
	Seoni	Balfour's Cyclopædia.		
	NAGPUR DIVISION—			
	Balaghat—			
	Lanji	Man. III. 202; Cent. Prov. Gazetteer; As. Res., XVIII. 213; Calc. Jour. Nat. Hist. III. 292.	...	Auriferous sands.
	Mau	Qr. Jour. Geol. Soc., XI. 380.		
	Panchera.	Cent. Prov. Gazetteer.		
	Bhandara—			
	Ambagarh	Man. III. 201	...	Three professional gold-washers; auriferous sands.
	Thirora	" "		
	Chanda	" 202	...	Six professional gold-washers; auriferous sands eastern part of district.
	Nagpur	" 203	...	One hundred and three gold-washers.
	Wardha	" 203	...	Twenty-six gold-washers.
	UPPER GODAVERI DISTRICT—			
	Bhadrachellum	Man. III. 203; Cent. Prov. Gazetteer, 506.	...	Seldom washed for.
	Marigudem	Do. do.	...	Still washed at times.
	Bastar (Native State)	Man. III, 204.		
	Bharamgarh	Cent. Prov. Gazetteer.		
	Pratappur (Partabpur).			

CENTRAL PROVINCES—*continued.*

MISCELLANEOUS MINERALS.

Alum, *Alm.* Antimony Ores, *Ant.* Arsenical Minerals, *Ars.* Asbestus, *Asb.* Bismuth and Cobalt Ores, *B. C.* Borax, *Bx.* Chrome Ores, *Chr.* Copper Ores, *Cop.* Corundum, *Cor.* Gypsum, *Gyp.* Lead Ores, *Ld.* Magnesia Minerals, *Mag.* Manganese Ores, *Man.* Mica, *Mi.* Natron, *Nat.* Nitre, *Nit.* Ochres, *Ochr.* Phosphates, *Pho.* Platinum, *Plt.* Plumbago, *Plm.* Soapstone, *Sop.* Soda Salts, *Sod.* Sulphur, *Sul.* Tin Ores, *Tn.* Zinc Ores, *Znc.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
COPPER ORES, *Cop.*	CHHATTISGARH— Bilaspur— Lurmi	...	...	North of: traces observed by P. N. Bose.
	Ratanpur	Rec. XVIII. 176	...	Trace.
	Raipur— Chicoli	Man. III. 256; Rec. X. 185.	LD.	Traces.
	Wararbund	Man. III. 256; Rec. X. 185.		
	JABALPUR— Jabalpur District— Sleemanabad	Man. III 257; Rec. III. 70.	LD.	Trace.
	NAGPUR DIVISION— Balaghat— Malanj Khandi	Rec. XIX. 165	SND.	Old mines; worked out
	Chanda— Thana Wasa	Man. III. 257; C P. Gazetteer, 135.	...	Old mine, traditionary.
	NARBADA DIVISION— Narsingpur— Birmanghat	Man. III. 257; Rec. VII. 62.	..	Narbada Coal and Iron Company's property. Experimental mining in 1873.
CORUNDUM *Cor.*	? NAGPUR DIVISION— Pohora	Man. III. 424; Jour. As. Soc. Beng., XIX. 489.	..	Doubtful.
	UPPER GODAVERI DISTRICT— Bhadrachellum	Man. III. 424	...	Doubtfu
LEAD ORES, *Ld.*	CHHATTISGARH DIVISION— Raipur— Chicoli (Ranitalao)	Man. III. 296; Rec. I. 37; Rec. II. 101.	COP.	Well marked vein.
	Sambalpur— Jhunan	Man. III. 295; Rec. X. 191.	ANT., COP.	Silver lead ore. Zinc lode.

CENTRAL PROVINCES—*continued.*

MISCELLANEOUS MINERALS—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
LEAD ORES, *Ld.—contd.*	CHATTISGARH DIVISION —*contd.*			
	Sambalpur—*contd.*			
	Padampur . .	Man. III. 295; Rec. X. 192.	LIM. . .	Traces in Vindhyan limestone.
	Talpuchia . .	Man. III. 295; Rec. X. 192.	...	Rolled pebbles; original site unknown, but may be this place.
	JABALPUR DIVISION—			
	Jabalpur—			
	Sleemanabad . .	Man. III. 297; Rec. III. 70.	COP.	
	NAGPUR—			
	Nagpur—			
	Nimbha (or Nima)	Man. III. 298; As. Res. XVIII. 198.	...	Loose boulders; source unknown.
	NARBADA DIVISION—			
	Hoshangabad—			
	Joga . .	Man. III. 297; Rec. XII. 174.	...	Old mines.
MANGANESE ORES, *Man*	JABALPUR—			
	Jabalpur—			
	Bhatadon . .	Man. III. 328; Rec XII. 99; XXI. 84.	I. . .	Pyrolusite, 76,000 tons available in this region: between Gosalpur and Sihora.
	Chindamani . .	Man. III, 328; Rec. XII. 99; XXI. 86.	I.	
	Darsani . .	Man. III, 328; Rec. XII. XXI. 73—79.		Associated with manganiferous hematites and laterite. Generally called the Gosalpur manganese ore field.
	Dhangaon . .			
	Dhanwai . .		I.	
	Dharampur . .			
	Gosalpur . .		I. LTE.	
	Khatola . .		I.	
	Mungeli . .			
	Mangela . .			
	Murhasan . .			
	Naigain . .			
	Pararia . .			
	Ponri . .			
	Sihora . .			
	NAGPUR—			
	Balaghat—			
	Burha.			
	Bhandara—			
	Ambagarh.			
	Nagpur—			
	Kodaigowan . .	Man. III. 330.		
	Ramtek . .	" 329; Rec. XII. 73.		

CENTRAL PROVINCES—*continued.*

MISCELLANEOUS MINERALS—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
MICA, *Mi.* (Erroneously called Talc; Mica is an elastic mineral, Talc is only flexible, and seldom in plates.)	NAGPUR— Balaghat— Bamni . . Chitadongri . .	Man. III. 528; C. P. Gazetteer, 18.	...	So far, plates too small in size to be of any value.
OCHRES *Ockr.*	CHHATTISGARH— Raipur— Gandai Zemindari.	...	I. SND. .	Red ochre; carried great distances.
	Mandanpur . . Thakurtola . .	C. P. Admn. Rep., 1861-62, 123.	...	Red ochre.
	JABALPUR— Jabalpur— Jauli . .	Man. III. 417.		
	NAGPUR— Balaghat— Salitekri Hills .	C. P. Gazetteer, 18.		
	Seukcindan (Larihee Hills).	Cal. Jour. Nat. Hist., III. 290.		
	Chanda . .	Man. III. 418.		
PLUMBAGO, *Plm.*	CHHATTISGARH— Sambalpur— Daramgarh . . Domaipali . . Lanjigaon (Kalahandi State).	Man. III. 53 .	...	Impure.
SOAP-STONE, *Sop.* (Includes steatite, potstone, talc (not mica) 'bulpum').	JABALPUR . .	Man. III. 443; Mem. II. 137.		
	Jabalpur . .	Calc. Jour. Nat. Hist., III. 291.		
	Marble Rocks . .	Rec. XXII. 64 .	...	Supply said to be abundant and excellent.
	NAGPUR DIVISION— Bhandara— Biroli, Nr. Tharora	Man. III, 443;	...	Pale colored; potstone.
	Kanheri Village .	Ditto Rec. XXII. 64	...	Lte., Steatite.
	Chanda— Jambal Ghat. .	Man. III. 443; Q. J. G. S. XI. Pt. iii, 380.	...	Potstone.
TIN ORES, *Tn.*	UPPER GODAVERI DISTRICT— Native Principality— Bastar— Patargudiem .	Man. III. 315.		

CENTRAL PROVINCES—*continued.*

GEM-STONES, &c.

Amber, *Amb.* Beryl, *Brl.* Diamond, *D.* Garnet, *Gar.* Jade, and Jadeite. *Jd.* Quartz. *Q.* Rubellite, *Rbl.* Ruby, *R.* Sapphire, *S.* Spinel, *Spl.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
DIAMOND, *D.*	CHHATTISGARH—Sambalpur—			
	Sambalpur, near	Man. III. 30; Asiæ X Tab. "Geographiæ Libri Octo, Gr. et Lat. Opera P. Bertii, Lugduni;" Bat. 1618. Fol.	Amethyst, carnelian, clear quartz.	Sand washings in the Mahanadi above the town of Sambalpur, near an island called Hira Khund.
	Native States—Gangpur	Tab. X. "Cosmographiæ," Libri VIII., Lat., Justi de Albano, Ulmæ;) 1486, Fol.		
	Jashpur	"Asiatic Annual Register," London, 1799.		
	Raigarh	Jour. As. Soc., Beng., XIII. 1844, 859; "Medical Topography of the districts of Ramgarh, Chotanagpur, Sirgooja, and Sambalpur," 1825, by P. Breton; Transactions of the Medical and Physical Society of Calcutta, Vol II, 1826; Jour. As. Soc., Beng., VIII, 1839, 375; Sel. from Rec. Beng. Govt., No. XXIII, 1852; Sel. from Rec. Mad. Govt., No. XIV, 1855; Karl Ritter's Erd. Kunde Asien, Vol. VI, 343; Rec. X, 186.		
	NAGPUR—Chanda—Wairagarh	Man. III. 37; "Ain i-Akbari," Gladwin's Translation, London, 1800, Vol. II, 58;	...	Old mines, in lateritic deposit.

CENTRAL PROVINCES—*continued.*

GEM-STONES, &c.—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals	REMARKS.
DIAMOND, *D.—contd.*	NAGPUR—*contd.* Chanda—contd. Wairagarh—contd.	Ferishta's History, Ed. by J. Briggs, London, 1819 .Vol. II, 416.		
	The Sath River .	R. Jenkins' Report on the territories of the Raja of Nagpur. Calcutta, 1827, 14; Cal. Jour. Nat. Hist., III, 290; Q. J. G. Soc., Lond., XI, 355; Jour. Bomb. Br. Roy. As. Soc., I, 520; Rep. on the Archæological Survey of India, VII. 129.		
GARNET, *Gar.*	UPPER GODAVERI DISTRICT— Bhadrachellum .	Man. III. 523.		
QUARTZ . (Includes rock crystal and the various forms of quartz, as agate, amethyst, bloodstone, chalcedony, chert, flint, jasper, onyx, opal, &c.)	CHHATTISGARH— Sambalpur— Bijkomar . .	Man. IV. 63 .	...	Rock crystal.
	JABALPUR	Man. III. 806; IV. 72.	...	Agates, chalcedony, &c., from the Deccan trap formation. Also crystalline quartz, or rock crystal, moss agate, Mocha stones, onyx. Mostly pebbles from the bed of the Narbada; sometimes Carnelian.
	Mandla . . .	Man. III. 860; IV. 72.		
	NAGPUR DIVISION— Chanda— Ballapur . .	Ain-i-Akbari (Gladwin's Edition) Vol. II. 58.	...	Agates.
RUBY, *R.* .	CHHATTISGARH— Sambalpur— Sambalpur . .	Jour. As. Soc.,Beng. VIII, 372.	...	Doubtful.

CENTRAL PROVINCES—*continued.*

QUARRY STONES.

Clays, *Cly.* Granite, Gneiss &c., *Grt.* Laterite, *Lte.* Limestone, Marbles, Kunkar, &c., *Lim.* Sandstones, *Snd.* Slate, *Slt.* Trap, Basalt, &c., *Trp.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
CLAYS, *Cly.*	JABALPUR DIVISION—			
	Jabalpur –			
	Amdari (Umaria) .	Rec. XXII. 140	...	Pottery clays.
	Chota Simla Hill .	Rec. XXII. 140	...	Very promising.
	Lameta . .	Rec. XXII. 140	C.	
	Mahanadi R. .	Rec. XXII. 140	...	Pottery clays.
	Marjadlia Valley .	Rec. XXII. 140	...	Ditto.
	Umaria Coal-field .	Rec. XXII. 140	C. . .	Fire clay.
GRANITE. &c., *Grt.* (Includes all fairly compact crystalline rocks; as gneisses of all kinds, generally of grey greenish or flesh colors. Not compact massive black or dark green rocks, such as basalt, trap, &c.)	Common in eastern portion of Nagpur Division, and northern parts of the Bilaspur District; also in the neighbourhood of Jabalpur; and along the southern edge of the Mandla, Seoni, and Chhindwara basaltic plateau. Likewise in the Chanda District about the Waingunga.			
LATERITE, *Lte.*	Only very locally distributed over, and bordering on the basaltic plateaux: in the divisions of Chhattisgarh (Raipur) Jabalpur, and Nagpur.			
LIME-STONE, &c., *Lim.* (Includes most marbles of different kinds, calcareous flag-stones, kunkar or ghutin, travertine: also, for convenience, serpentines and alabastar.	CHHATTISGARH—			
	Raipur . . .	Man. III. 460 .	LTE., SND. .	Vindhyan limestone. Abundant rock, thick beds, flags, &c., over Chhattisgarh plains. Also kunkar.
	Sambalpur.—			
	Bolangir . .	Rec. X. 178, 182, 183.	SND. .	Also kunkar. Vindhyan limestone.
	Kujerma . .	Rec. X. 178, 182, 183.	SND. .	Also kunkar. Vindhyan limestone.
	Padampur on the Mahanadi and southwards.	Rec. X. 178, 182, 183.	SND. .	Also kunkar. Vindhyan limestone.
	JABALPUR—			
	Damoh . .	Man. III. 462.		

CENTRAL PROVINCES—*continued.*

QUARRY STONES—*continued.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
LIME-STONE, &c., *Lim.—contd.*	JABALPUR—			
	Kutni	......	...	Lime-burning largely.
	Marble Rocks	......	SOP.	Dolomite marble.
	Marwara	Man. III. 460.		Lime-burning.
	Sleemanabad			
	NAGPUR DIVISION—			
	Chanda—			
	Kandara, 6 miles north of Warora.	Mem. XIII. 113	...	Kunkar, abundant.
	Karamgohan			
	Mardha			
	Nilja, 2 miles south of Warora.			
	Nagpur—			
	Chicholi	Mem. IX. 302, 330.		
	Kelod			
	Korhadi	......	...	Crystalline limestone.
	Mahadula	Mem. XIII. 172	...	Kunkar.
	Wardha			
	NARBADA DIVISION—			
	Chhindwara—			
	Bakur.			
	Enkawari.			
	Hoshangabad (western portion).			
	Narsingpur—			
	Bambari.			
	Bichna.			
	Khariri.			
SAND-STONES, *Snd.* (Includes any sandy rock used for building, even calcareous sandstones, flags; also quartzites, which are only indurated sandstones, Pebbly rocks.)	CHHATTISGARH DIVISION—			
	Raipur—			
	Raipur	Man. III. 546	...	Limestone beds.
	Sambalpur	" "	...	
	JABALPUR DIVISION—			
	Jabalpur—			
	Jabalpur	Rec. V. 77	...	
	NAGPUR DIVISION—			
	Nagpur—			
	South of Nagpur	Man. III. 546	...	
	NARBADA DIVISION—			
	Hoshangabad—			
	Chirakhan	Mem. XXI, 70	...	

CENTRAL PROVINCES—*concluded.*

QUARRY STONES—*concluded.*

Mineral or Stone.	Locality.	Reference.	Other Minerals.	REMARKS.
SLATE, *Slt.* (Includes flags, though these are cleaved like slates.)	NAGPUR DIVISION— Chanda . . . NARBADA DIVISION— Chhindwara . .	Adm. Rep., Cent. Prov., 1866-67, 80.		
TRAP, *Trp.* (Includes basalt, whinstone and other compact massive dark colored rocks.)	A large portion of Central Provinces.	Man. III. 538.		Forming a considerable portion of the great Deccan Trap plateau. Trap and basalts of all kinds.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

1. ENDING NOVEMBER 1st, 1889.

Director's Office, Calcutta, November 1889.

The staff of the Survey is at present disposed in the following parties :—

Madras Party.—R. B. FOOTE, F.G.S., Senior Superintendent, Bellary District.

Burma Party.—THEO. W. HUGHES HUGHES, A.R.S.M., Superintendent.
TOM D. LATOUCHE, B.A., Deputy Superintendent.

Mr. Hughes returned from privilege leave on the 4th October; and is engaged in tin exploitation in Tenasserim. Mr. LaTouche is at present engaged on a survey of the Lakadong coal-field in Assam, but is under orders to accompany the Chittagong Column of the Chin-Lushai Expedition, sailing with troops from Calcutta about 20th November.

Baluchistan Party.—R. D. OLDHAM, A.R.S.M., 1st Grade Deputy Superintendent.
PHILIP LAKE, B.A., Assistant Superintendent.
————————(Not filled yet).
Sub-Assistant Kishen Singh.
Sub-Assistant Hira Lal.

This party is formed for full exploration of coal and oil: under immediate orders of the Agent to the Governor-General in Baluchistan. Assembled at Quetta early in October.

Salt Range Party.—C. S. MIDDLEMISS, B.A., Deputy Superintendent.
P. N. DATTA, B.SC., Assistant Superintendent.

Darjiling and Sikhim.—P. N. BOSE, B.SC., Deputy Superintendent.

Mr. Bose left for Sikhim early in September, and joined Mr. White the Political Officer; returning to Darjiling in the beginning of November, whence he takes up further search for coal in the Western Dooars.

Head Quarters, Calcutta.—The Director; Palæontologist; and Officer in charge of Museum and Laboratory.

The Director has to record with deep regret the untimely death of Mr. E. J. Jones, A.R.S.M., Deputy Superintendent and Officiating Curator, at Darjiling, on the 15th October. Mr. Jones was a very promising and reliable officer, especially in Mineralogy and Chemistry, and his loss to the Survey is great. As Vice-President of the Microscopical Society of Calcutta, he was also doing valuable work outside the Department.

List of Reports or Papers sent in to Office for publication or record during August, September and October.

Author.	Subject.	Disposal.
C. L. GRIESBACH, C.I.E.	Geological Notes, Spiti	Published in the Records of the Geological Survey of India, Vol. XXII, part 3.
TOM D. LA TOUCHE	Report on the Cherra Poonjee Coal-field.	Ditto ditto.
E. J. JONES	Note on a Cobaltiferous Matt from Nepal.	Ditto ditto.
R. LYDEKKER, Harpenden, Herts.	Land-Tortoises of the Siwaliks	To appear in the Records of the Geological Survey of India, Vol. XXII, part 4.
Ditto	Pelvis of Ruminant from the Siwaliks.	Ditto ditto.
DR. H. WARTH, Forest Department.	Sambhar Salt Lake Assays	Ditto ditto.
P. N. BOSE	Manganiferous Iron and Manganese Ores of Jabalpur.	Ditto ditto.
C. S. MIDDLEMISS	Palagonite Traps from Rajmahal Hills and the Deccan.	Ditto ditto.
THEO. W. H. HUGHES	Tin Smelting in the Malay Peninsula.	Ditto ditto.
DR. W. KING	Provisional Index of Minerals in Indian Empire, 1st part.	Ditto ditto.
R. D. OLDHAM	Memorandum on Protective Works, Naini Tal.	Record.
H. B. MEDLICOTT, F.R.S., CLIFTON.	Index to his papers in the 2nd ten volumes of the Records.	For Index to the 1st twenty volumes of the Records.
V. BALL, F.R.S., DUBLIN.	Ditto ditto	Ditto ditto.
A. B. WYNNE, H.M's. Geological Survey of Ireland.	Ditto ditto	Ditto ditto.
DR. OTTOKAR FEISTMANTEL, PRAGUE.	Ditto ditto	Ditto ditto.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September and October 1889.

<table>
<tr><th>Substance.</th><th>For whom.</th><th>Result.</th></tr>
<tr><td>Decomposing pyritous shale, from Corriari Valley.</td><td>W. MacClagan Reid, Rohtasgarh.</td><td>Contains SO_2 FeO″; some SO_2 BaO″; and free SO_2 HO_2.</td></tr>
<tr><td>Carbonate of copper from Belbathan, Santal Parganas.</td><td>J. Reginald Hand, Sub-Divisional Officer, Godda.</td><td>Contains 48·83 per cent. of copper.</td></tr>
<tr><td>7 samples of coal, from the Chindwin and Irrawaddi coal-fields, Upper Burma.</td><td>F. Noetling, Geological Survey of India.</td><td>
<table>
<tr><th></th><th>Peluswa Chindwin, 2′ seam.</th><th>Peluswa Chindwin, 2′ seam.</th><th>Peluswa Chindwin, 3′ seam.</th><th>Peluswa Chindwin, 4′ seam.</th><th>Mantha Irrawadi valley, 4′ seam.</th><th>Nautahin valley, Chindwin, 4′ seam (highest.)</th><th>Nautahin valley, Chindwin, 12′ seam.</th></tr>
<tr><td>Moisture</td><td>9·40</td><td>9·38</td><td>9·42</td><td>11·24</td><td>9·20</td><td>10·10</td><td>10·60</td></tr>
<tr><td>Volatile matter</td><td>28·34</td><td>34·02</td><td>37·60</td><td>39·94</td><td>33·56</td><td>36·16</td><td>33·96</td></tr>
<tr><td>Fixed carbon</td><td>40·36</td><td>50·38</td><td>49·54</td><td>45·06</td><td>34·08</td><td>46·38</td><td>47·24</td></tr>
<tr><td>Ash</td><td>21·90</td><td>6·22</td><td>3·44</td><td>3·76</td><td>23·16</td><td>7·36</td><td>8·20</td></tr>
<tr><td>Total</td><td>100·00</td><td>100·00</td><td>100·00</td><td>100·00</td><td>100·00</td><td>100·00</td><td>100·00</td></tr>
<tr><td>Color of ash</td><td>Pale buff.</td><td>Pale buff.</td><td>Buff.</td><td>Buff.</td><td>Light grey.</td><td>Dirty grey.</td><td>Dirty buff.</td></tr>
</table>
None of the coals cake, but they all sinter slightly.</td></tr>
<tr><td>Metallic lead from near Maymio, Upper Burma.</td><td>F. Noetling, Geological Survey of India.</td><td>Contains 8 oz. silver to the ton of lead, and an appreciable quantity of arsenic, and a trace of Fe.</td></tr>
<tr><td>Coal from the Sarakula Valley, 8¼ miles from Quetta.</td><td>D. Morris, Engineer in charge Coal Mines, N. W. Railway, Sukkur.</td><td>
<table>
<tr><td>Moisture</td><td>7·04</td></tr>
<tr><td>Volatile matter</td><td>37·04</td></tr>
<tr><td>Fixed carbon</td><td>51·86</td></tr>
<tr><td>Ash</td><td>4·06</td></tr>
<tr><td>Total</td><td>100·00</td></tr>
</table>
Cakes, but not strongly. Ash, dark red.</td></tr>
</table>

Notifications by the Government of India during the months of August, September and October 1889, published in the "Gazette of India," Part I.—Appointment, Confirmation, Promotion and Retirement.

Department.	Number of order and date.	Name of Officer.	From	To	Nature of Appointment, &c.	With effect from	REMARKS.
Foreign Department.	1177F., dated 25th July 1889.	C. L. GRIESBACH.	Deputation.	1st Grade Deputy Superintendent.	Rejoining	23rd July 1889.	Return from deputation to Afghanistan.
Revenue and Agricultural Department.	$\frac{344}{17\text{-}8}$ S., dated 6th August 1889.	E. J. JONES.	...	...	Officiating Curator.	22nd June 1889.	
Revenue and Agricultural Department.	$\frac{507}{17\text{-}15}$ S., dated 9th October 1889.	C. L. GRIESBACH.	1st Grade Deputy Supdt.	Superintendent.	Promotion	22nd June 1889.	
Revenue and Agricultural Department.	$\frac{507}{17\text{-}15}$ S., dated 9th October 1889.	R. D. OLDHAM.	Officiating 1st Grade Deputy Supdt.	1st Grade Deputy Supdt.	Do.	22nd June 1889.	

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Notifications by the G[illegible] India during the months of August, September and October [illegible]ed in the "Gazette of India," Part I.—Leave.

Department.	Num[illegible] order [illegible] date.	Name of Officer.	Nature of Leave.	With effect from	Date of Return.	REMARKS.
Revenue and Agricultural Department.	$\frac{352}{17\text{-}10}$ S., dated 8th August 1889.	THEO. W. H. HUGHES	Privilege leave.	15th July 1889.	4th October 1889.	For 2 months and 23 days.

Annual Increments to graded Officers, sanctioned by the Government of India during August, September and October 1889.

Name of Officer.	From	To	With effect from	Number and date of sanction.	REMARKS.
	Rs.	Rs.			
E. J. JONES . .	500	540	1st July 1889.	$\frac{338}{13\text{-}7}$ S., dated 2nd Aug. 1889.	
P. LAKE . . .	380	410	1st Aug. 1889	$\frac{368}{13\text{-}9}$ S., dated 15th Aug. 1889.	
Tom D. LA TOUCHE.	540	580	1st Oct. 1889	$\frac{585}{13\text{-}11}$ S., dated 30th Oct. 1889.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal Address.	Nearest Telegraph Office.
R. BRUCE FOOTE . . .	Bellary (Madras) . .	Bellary.
T. W. H. HUGHES . . .	Mergui (Burma) . .	Tavoy.
C. L. GRIESBACH . . .	Calcutta	Park Street, Calcutta.
R. D. OLDHAM	Quetta (Baluchistan). .	Quetta.
P. N. BOSE	Kalimpong (Darjeeling) .	Kalimpong.
T. H. D. LA TOUCHE . .	Shillong (Assam) . .	Shillong.
C. S. MIDDLEMISS . . .	Khewra (Jhelum) . .	Khewra.
P. LAKE	Quetta (Baluchistan) .	Quetta.
P. N. DATTA	Lahore	Lahore.
F. NOETLING	Calcutta	Park Street, Calcutta.
KISHEN SING	Quetta (Baluchistan) . .	Quetta.
HIRA LAL	Do. do. . .	Do.

ADDITIONS TO THE MUSEUM.

FROM 1ST OCTOBER TO 31ST DECEMBER 1888.

Inspissated petroleum, petroleum, and fireclay, from South Lakimpur; portion of a fossil elephant's tooth, from Debrugarh, and some sulphuric acid, from the Shoran Sulphur Mine. PRESENTED BY R. A. TOWNSEND.

Matrix of the diamond (known locally as 'blue'), from Griqualand, South Africa.
PRESENTED BY R. BATEMAN-SMYTHE.

Model of the Indian Diamond "Gor-do-Norr," before and after cutting, found near Vujra Karur, Bellary District, Madras.
PRESENTED BY MESSRS. P. ORR & SONS, MADRAS.

Copper smelted at Chunabatti, Alipore sub-division, Jalpaiguri.
PRESENTED BY THE GOVERNMENT OF BENGAL.

Samples illustrating the smelting of lead from argentiferous galena, and extraction of silver from the lead, from the mines of the Myelat, Bawzaing, Ngwegunhmu, (Shan States, Burma).
PRESENTED BY THE FINANCIAL COMMISSIONER, BURMA.

A cake of cobaltiferous matt, from Kachipatar, Argah Zillah, Sowrobhar, about 8 miles north of Doolha. PRESENTED BY THE RESIDENT IN NEPAL.

ADDITIONS TO THE LIBRARY.

FROM 1ST OCTOBER TO 31ST DECEMBER 1888.

Titles of Books. *Donors.*

BLANFORD, *William Thomas.*—Note sur la classification des roches de l'Inde Britannique. 8° Pam. Berlin, 1885. THE AUTHOR.

BRONN'S Klassen und Ordnungen des Thier-Reichs. Band VI, abth. III, Reptilien, lief. 61-62; and Abth. IV, Aves, lief 21-22. 8° Leipzig, 1888.

COAL.—Correspondence relating to the Beddadanole Coal Field. Flsc. Madras, 1873-1876. DR. WILL. KING.

McGEE, *W. J.*—Three formations of the Middle Atlantic Slope. 8° Pam. New Haven, 1888. THE AUTHOR.

McIVOR, *William Graham.*—Description of an invention for removing or destroying the momentum, or overcoming the inertia of heavy bodies. 4° Madras, 1865. DR. WILL. KING.

MITCHELL, *John.*—A Manual of Practical Assaying. 6th edition, by William Crookes. 8° London, 1888.

MOJSISOVICS, *E. v.*, and NEUMAYR, *M.*—Beiträge zur Paläontologie Österreich-Ungarns und des Orients. Band VI, heft 4, and Band VII, heft 1-2. 4° Wien, 1888.

MORGANS, W.—Criticisms on stationary steam boilers; directed especially to matters of construction, tests of quality, and to the discriminating choice of boilers. 12° London, 1881. THEO. W. H. HUGHES.

Titles of Books. *Donors.*

MORGANS, W.—The solution of Colliery Explosions. Part I. The foe entrenched. 8° Bristol, 1887. THEO. W. H. HUGHES.

RUTLEY, *Frank.*—Rock-forming Minerals. 8° London, 1888.

STEINMANN, *Gustav*, and DÖDERLEIN, *Ludwig.*—Elemente der Paläontologie. Hälfte I. 8° Leipzig, 1888.

THOMSON, *Sir C. Wyville*, and MURRAY, *John.*—Report on the scientific results of the voyage of H. M. S. Challenger during the years 1873-76. Zoology, Vols. XXIII—XXVI. 4° London, 1888. SECRETARY OF STATE.

TRYON, *George W.*—Manual of Conchology. Vol. X, pt. 2, and 2nd series, Vol. IV, pt. 2. 8° Philadelphia, 1888.

ZEILLER, R.—Études des Gites Minéraux de la France. Bassin Houiller de Valenciennes. Description de la Flore Fossile. Texte and atlas of plates. 4° Paris, 1888. THE AUTHOR.

PERIODICALS, SERIALS, &c.

American Journal of Science. 3rd series, Vol. XXXVI, Nos. 213-215. 8° New Haven, 1888. THE EDITORS.

American Naturalist. Vol. XXII, Nos. 257-260. 8° Philadelphia, 1888.

Annalen der Physik und Chemie. Neue Folge, Band XXXV, heft 2-3. 8° Leipzig, 1888.

Annales des Sciences Géologiques. Tome XIX and Tome XX, Nos. 1-2. 8° Paris, 1888.

Annales des Sciences Naturelles. 7me série, Zoologie et Paléontologie. Tome V., Nos. 1-6. 8° Paris, 1888.

Annales des Sciences Naturelles. 7me série, Botanique. Tome VII, Nos. 2-6. 8° Paris, 1888.

Annals and Magazine of Natural History. 6th series, Vol. II, Nos. 10-12. 8° London, 1888.

Archiv für Naturgeschichte. Jahrg. LII, Band II, heft 3; Jahrg. LIV, Band I, heft 1, und Band II, heft 2. 8° Berlin, 1886 and 1888.

Athenæum. Nos. 3177-3188. 4° London, 1888.

Beiblätter zu den Annalen der Physik und Chemie. Band XII, Nos. 9-10. 8° Leipzig, 1888.

Chemical News. Vol. LVIII, Nos. 1503-1514. 4° London, 1888.

Colliery Guardian. Vol. LVI, Nos 1446-1457. Fol. London, 1888.

Geographische Abhandlungen. Band III, heft 2. 8° Wien, 1888.

Geological Magazine. New series, Decade III, Vol. V, Nos. 10-11. 8° London, 1888.

Geological Record for 1880—1884 (inclusive). Vol. I. 8° London, 1888.

Indian Engineering. Vol. IV, Nos. 14-25. Flsc. Calcutta, 1888. P. DOYLE.

Iron. Vol. XXXII, Nos. 818-829. Fol. London, 1888.

Journal de Conchyliologie. 3me série, Tome XXVIII, No. 3. 8° Paris, 1888.

Journal of Analytical Chemistry. Vol. I, pts. 1-4, and Vol. II, pts. 1-3. 8° Easton, Pa. 1887-1888. JOHN EYERMAN.

London, Edinburgh and Dublin Philosophical Magazine and Journal of Science. 5th series, Vol. XXVI, Nos. 161-163. 8° London, 1888.

Titles of Books. *Donors.*

Mining Journal. Vol. LVIII, Nos. 2768-2779. Fol. London, 1888.

Naturæ Novitates. Jahrg. X, Nos. 18-22. 8° Berlin, 1888.

Nature. Vol. XXXVIII, No. 985 to Vol. XXXIX, No. 996. 4° London, 1888.

Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Beilage-Band VI, heft 1. 8° Stuttgart, 1888.

Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Jahrgang 1888, Band II, heft 3. 8° Stuttgart, 1888.

Palæontographica. Band XXXV, lief. 1. 4° Stuttgart, 1888.

Palæontologische Abhandlungen. Band IV, heft 3. 4° Berlin, 1888.

Petermann's Geographische Mittheilungen. Band XXXIV, Nos. 10-11. 4° Gotha, 1888. THE EDITOR.

Petermann's Geographische Mittheilungen. Supplement, No. 91. 4° Gotha, 1888. THE EDITOR.

Quarterly Journal of Microscopical Science. New series, Vol. XXIX, pt. 2. 8° London, 1888.

The Indian Engineer. New series, Vol. V, No. 24, and Vol. VI, Nos. 1-11. 4° Calcutta, 1888. NEWMAN & Co.

Zeitschrift für Naturwissenschaften. Folge 4, Band VII, heft 2. 8° Halle, 1888.

GOVERNMENT SELECTIONS, REPORTS, &c.

BENGAL.—Quarterly Bengal Army List. New series, No. 106. 8° Calcutta, 1888. GOVERNMENT OF INDIA.

BOMBAY.—Selections from the Records of the Bombay Government. New series, Nos. 221-223. Flsc. Bombay, 1888. BOMBAY GOVERNMENT.

BURMA.—Report and Gazetteer of Burma, Native and British. By Major Douglas Macneill. Parts 1-3. 8° Simla, 1883. QUARTER MASTER GENERAL IN INDIA.

INDIA.—Indian Meteorological Memoirs. Vol. IV, pt. 5. 4° Calcutta, 1888. METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Registers of Original Observations in 1888, reduced and corrected. May to July. 4° Calcutta, 1888. METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Report on the administration of the Meteorological Department of the Government of India in 1887-88. 4° Calcutta, 1888. METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Selections from the Records of the Government of India, Foreign Department. No. 245. Flsc. Calcutta, 1888. GOVERNMENT OF INDIA.

PUNJAB.—Gazetteer of the Punjab: Provincial Volume, 1888-9. 8° Calcutta, 1888. PUNJAB GOVERNMENT.

TRANSACTIONS, PROCEEDINGS, &c., OF SOCIETIES, SURVEYS, &c.

Titles of Books. *Donors.*

ALBANY.—Annual reports of the Regents of the University of the State of New York, on the condition of the State Cabinet of Natural History. Nos. XXII—XXIII. 8° Albany, 1869 and 1873.
NEW YORK STATE MUSEUM.

" Annual reports on the New York State Museum of Natural History. Nos. XXIV—XXVI & XXXII—XXXV. 8° Albany, 1872-1884.
NEW YORK STATE MUSEUM.

BATAVIA.—Nederlandsch-Indisch Plakaatboek, 1602-1811, door J. A. Van der Chijs. Deel V, 1743-1750. 8° Batavia, 1888. BATAVIAN SOCIETY.

BERLIN.—Zeitschrift der Deutschen geologischen Gesellschaft. Band XL, heft 2. 8° Berlin, 1888. THE SOCIETY.

BOSTON.—Memoirs of the Boston Society of Natural History. Vol. IV, Nos. 5-6. 4° Boston, 1888. THE SOCIETY.

BRISBANE.—Annual report of the Trustees of the Queensland Museum for 1887. Flsc. Brisbane, 1888. THE MUSEUM.

" Proceedings of the Royal Society of Queensland. Vol. V, pts 1-2. 8° Brisbane, 1888. THE SOCIETY.

BRUSSELS.—Annales du Musée Royal d'Histoire Naturelle de Belgique. Tome XIV, pt. 6. With atlas of plates. Fol. Bruxelles, 1887. THE MUSEUM.

" Bulletin de la Société Royale Belge de Géographie. Année XII, Nos. 3-4. 8° Bruxelles, 1888. THE SOCIETY.

BUENOS AIRES.—Boletin de la Academia Nacional de Ciencias en Cordoba. Tome XI, No. 1. 8° Buenos Aires, 1887. THE ACADEMY.

CAEN.—Bulletin de la Société Linnéenne de Normandie. 4^{me} série, Vol. I, 1886-87. 8° Caen, 1888. THE SOCIETY.

CALCUTTA.—A Bibliography of Indian Geology: being a list of books and papers, relating to the Geology of British India and adjoining countries, published previous to the end of A.D. 1887. Compiled by R. D. Oldham. 8° Calcutta, 1888. GEOLOGICAL SURVEY OF INDIA.

" Journal of the Asiatic Society of Bengal. New series, Vol. LVI, Part II, No. 5; Vol. LVII, Part I, No. 2, and Part II, No. 3. 8° Calcutta, 1888.
THE SOCIETY.

" Survey of India Department. Notes for August to October. Flsc. Calcutta, 1888. SURVEY OF INDIA DEPARTMENT.

CAMBRIDGE, MASS.—Bulletin of the Museum of Comparative Zoology. Vols. XIV, XV & XVII, No. 2. 8° Cambridge, Mass., 1888. THE MUSEUM.

CINCINNATI.—Journal of the Cincinnati Society of Natural History. Vol. XI, Nos. 2-3. 8° Cincinnati, 1888. THE SOCIETY.

DUBLIN.—Journal of the Royal Geological Society of Ireland. New series, Vol. VII, pt. 2. 8° Dublin, 1887. THE SOCIETY.

Titles of Books. *Donors.*

EDINBURGH.—Scottish Geographical Magazine. Vol. IV, Nos. 10-12. 8° Edinburgh, 1888. THE SOCIETY.

FRANKFURT-A-M.—Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft. Band XV, heft 3. 4° Frankfurt-a-M., 1888.

GLASGOW.—The Glasgow University Calendar for 1888-89. 8° Glasgow, 1888. THE UNIVERSITY.

GÖTTINGEN.—Nachrichten von der Königl. Gesellschaft der Wissenschaften aus dem Jahre 1887. 8° Göttingen, 1887. THE SOCIETY.

HARRISBURG.—Annual report of the Geological Survey of Pennsylvania for 1886. Part III, with Atlas; Atlas Western Middle Anthracite Field, pt. II A.A.; Atlas Bucks and Montgomery Counties, C 7. 8° Harrisburg, 1887. GEOLOGICAL SURVEY OF PENNSYLVANIA.

HOBART.—Papers and Proceedings of the Royal Society of Tasmania for 1887. 8° Hobart, 1888. THE SOCIETY.

LILLE.—Annales de la Société Géologique du Nord. Tome XIV. 8° Lille, 1887. THE SOCIETY.

LIVERPOOL.—Proceedings of the Liverpool Geological Society. Vol. V, pt. 4. 8° Liverpool, 1888. THE SOCIETY.

LONDON.—Journal of the Anthropological Institute of Great Britain & Ireland. Vol. XVIII, Nos. 1-2. 8°. London, 1888.

" Journal of the Iron and Steel Institute. No. 1. 8° London, 1888. THE INSTITUTE.

" Journal of the Linnean Society of London. Zoology: Vol. XX, No. 118; Vol. XXI, Nos. 130-131; Vol. XXII, Nos. 136-139. Botany: Vol. XXIII, Nos. 152-155; XXIV, Nos. 159-162. With List of Fellows for 1887-88. 8° London, 1887-1888. THE SOCIETY.

" Transactions of the Linnean Society of London. Zoology: 2nd series, Vol. III, pts. 5-6. Botany: 2nd series, Vol. II, pt. 15, and Vol. III, pt. 1. 4° London, 1887-1888. THE SOCIETY.

" Journal of the Royal Asiatic Society of Great Britain and Ireland. New series, Vol. XX, No. 3. 8° London, 1888. THE SOCIETY.

" Journal of the Society of Arts. Vol. XXXV, No. 1869 to Vol. XXXVII, No. 1880. 8° London, 1888. THE SOCIETY.

" Mineralogical Magazine and Journal of the Mineralogical Society. Vol. VIII, No. 37. 8° London, 1888.

" Proceedings of the Royal Geographical Society. New series. Vol. X, Nos. 8-11. 8° London, 1888. THE SOCIETY.

" Proceedings of the Royal Society. Vol. XLIV, No. 267. 8° London, 1888. THE SOCIETY.

" Proceedings of the Zoological Society of London for 1888. Parts II-III. 8° London, 1888. THE SOCIETY.

" Quarterly Journal of the Geological Society. Vol. XLIV, Nos. 175-176, with list of Fellows for 1888. 8° London, 1888. THE SOCIETY

Titles of Books. *Donors.*

MADRID.—Boletin de la Sociedad Geografica de Madrid. Tomo XXV, Nos. 1-2. 8°, Madrid, 1888. THE SOCIETY.

MELBOURNE.—Annual report of the Secretary for Mines and Water Supply on the working of the regulation and inspection of mines and mining machinery act during 1887. Flsc. Melbourne, 1888.

DEPARTMENT OF MINES, VICTORIA.

" Natural History of Victoria. Prodromus of the Zoology of Victoria. Decade XVI. 8° Melbourne, 1888. GOVERNMENT OF VICTORIA.

" Reports of the Mining Registrars for the quarter ending 30th June 1888. Flsc. Melbourne, 1888. MINING DEPARTMENT, VICTORIA.

" Transactions and Proceedings of the Royal Society of Victoria. Vol. XXIV, pts. 1-2. 8° Melbourne, 1887-1888. THE SOCIETY.

" Transactions of the Geological Society of Australasia. Vol. I, pt. 3. 8° Melbourne, 1888. THE SOCIETY.

MONTREAL.—Geological and Natural History Survey of Canada. Catalogue of Canadian Plants. Part IV, Endogens, by John Macoun. 8° Montreal, 1888. THE SURVEY.

NAPLES.—Atti della Reale Accademia delle Scienze Fisiche e Matematiche. Serie 2, Vols. I-II. 4° Napoli, 1888. THE SOCIETY.

" Rendiconto dell' Accademia delle Scienze Fisiche e Matematiche (Sezione della Societa Reale di Napoli). Serie 2, Vol. I, fasc. 1-12. 4° Napoli, 1887. THE SOCIETY.

NEWCASTLE-ON-TYNE.—Transactions of the North of England Institute of Mining and Mechanical Engineers. Vol. XXXVII, pt. 5. 8° Newcastle-on-Tyne, 1888. THE INSTITUTE.

NEW HAVEN.—Transactions of the Connecticut Academy of Arts and Sciences. Vol. VII, pt. 2. 8° New Haven, 1888. THE ACADEMY.

PARIS.—Annales des Mines. 8^{me} série, Tome XIII, livr. 2-3. 8° Paris, 1888.

DEPARTMENT OF MINES.

" Bulletin de la Société Géologique de France. 3^{me} série, Tome XVI, Nos. 5-6. 8° Paris, 1888. THE SOCIETY.

" Compte Rendu des Séances de la Société de Géographie. No. 14. 8° Paris, 1888. THE SOCIETY.

" Comptes Rendus des Séances de l' Académie des Sciences. Tomes 103-105. 4° Paris, 1886-1887. THE ACADEMY.

PHILADELPHIA.—Journal of the Academy of Natural Sciences. 2nd series, Vol. IX, pt. 2. 4° Philadelphia, 1888. THE ACADEMY.

" Journal of the Franklin Institute. 3rd series, Vol. XCVI, Nos. 3-5. 8° Philadelphia, 1888. THE INSTITUTE.

" Proceedings of the American Philosophical Society. Vol. XXV, No. 127. 8° Philadelphia, 1888. THE SOCIETY.

Titles of Books. *Donors.*

ROME.—Atti della Reale Accademia dei Linnei. Serie IV, Rendiconti, Vol. IV, Semestre I, fasc. 11-13, and Semestre II, fasc. 2-5. 8° Roma, 1888.
THE ACADEMY.

SALEM, MASS.—Proceedings of the American Association for the Advancement of Science. Vol. XXXVI. 8° Salem, 1888. THE ASSOCIATION.

ST. PETERSBURG.—Bulletin de l'Académie Impériale des Sciences. Tome XXXII, No. 2. 4° St. Pétersbourg, 1888. THE ACADEMY.

" " Mémoires de l' Académie Impériale des Sciences. 7^{me} série, Tome XXXVI, Nos. 1-2. 4° St. Pétersbourg, 1888. THE ACADEMY.

SYDNEY.—Annual report of the Department of Mines, New South Wales, for 1887. Flsc. Sydney, 1888. DEPT. OF MINES, NEW SOUTH WALES.

" Australian Museum. Catalogue of the Fishes in the collection of the Australian Museum. Part I, Recent Palæichthyan Fishes by J. Douglas Ogilby. 8° Sydney, 1888. THE MUSEUM.

" Report of the Trustees of the Australian Museum for 1887. Flsc. Sydney, 1888. THE MUSEUM.

" Journal and Proceedings of the Royal Society of New South Wales. Vol. XXII, pt. 1. 8° Sydney, 1888. THE SOCIETY.

" Memoirs of the Geological Survey of New South Wales. Palæontology. No. I. 4° Sydney, 1888. DEPT. OF MINES, NEW SOUTH WALES.

" Proceedings of the Linnean Society of New South Wales. 2nd series, Vol. III, pt. 2. 8° Sydney, 1888. THE SOCIETY.

TURIN.—Atti della R. Accademia delle Scienze di Torino. Vol. XXIII, disp. 13-15. 8° Torino, 1888. THE ACADEMY.

VENICE.—Atti del Reale Istituto Veneto di Scienze, Lettere ed Arti. Serie VI, Tomo VI, disp. 5-9. 8° Venezia, 1887-1888. THE INSTITUTE.

" Memorie del Reg. Istituto Veneto di Scienze, Lettere ed Arti. Vol. XXII, pt. 3. 4° Venezia, 1887. THE INSTITUTE.

VIENNA.—Verhandlungen der K. K. geologischen Reichsanstalt. Nos. 12-13. 8° Wien, 1888. THE INSTITUTE.

WASHINGTON.—Annual report of the Board of Regents of the Smithsonian Institution, Part II, 1885. 8° Washington, 1886. THE INSTITUTION.

" Bulletin of the Philosophical Society of Washington. Vol. X, 1887. 8° Washington, 1888. THE SOCIETY.

WELLINGTON.—Reports on the Mining Industry of New Zealand. Flsc. Wellington, 1888. MINING DEPARTMENT, NEW ZEALAND.

YOKOHAMA.—Transactions of the Asiatic Society of Japan. Vol. XVI, pt. 2. 8° Yokohama, 1888. THE SOCIETY.

MAPS.

BUCHAREST.—Harta geologica generala a Romaniei lucrata de membrii Biuroului Geologic sub directiunea domnului Gr. Stefanescu. XV—XIX, Maps. Bucharest. No date. THE BUREAU.

January 19th, 1889.

Govt. of India Central Printing Office.—No. 19 D. G. Survey.—18-2-89.—620.

ADDITIONS TO THE MUSEUM.

FROM 1ST JANUARY TO 31ST MARCH 1889.

Five specimens of Indianite, from Southern India; and three of Tscheffkinite, from Kantamala, Coromandel.
PRESENTED BY THE TRUSTEES OF THE BRITISH MUSEUM, LONDON.

Six specimens of fossil plants, from the coal-measures, Raniganj.
PRESENTED BY J. L. REUSS.

Nodule, from north of Port Blair, consisting of sand grains, cemented by carbonate.
PRESENTED BY COMMANDER A. CARPENTER, R.N.

Specimens of the Tabory, Alfianello, and Ogi meteorites.
PRESENTED BY THE TRUSTEES OF THE BRITISH MUSEUM, LONDON.

Specimens of fuller's earth, red granite, sand, limestone, and conglomerate, from Sind and Rajputana. PRESENTED BY HORACE BELL.

Igneous rock (?) from 'neck' at Wajra Karur, Bellary District.
PRESENTED BY MESSRS. P. ORR AND SONS, MADRAS.

ADDITIONS TO THE LIBRARY.

FROM 1ST JANUARY TO 31ST MARCH 1889.

Titles of Books. *Donors.*

BOSWORTH-SMITH, *P.*—Report on the Kolar Gold-Field and its southern extension, in which the auriferous rocks are traced from the Mysore State into the Madras Presidency. Flsc. Madras, 1889.
REVENUE AND AGRICULTURAL DEPARTMENT.

BRONN'S Klassen und Ordnungen des Thier-Reichs. Band I, Protozoa, lief. 50-55; Band II, Abth. III, lief. 1; Band V, Abth. II, lief. 20; Band VI, Abth. III, lief. 63-64. 8° Leipzig, 1888-1889.

DE LA NOË, *G.*, and MARGERIE, *Emm. de.*—Les formes du Terrain. 4° Paris, 1888.
THE AUTHORS.

Encyclopædia Britannica. 9th edition. Vol. XXIV. 4° Edinburgh, 1888.

FRITSCH, *Dr. Ant.*—Fauna der Gaskohle und der Kalksteine der Permformation Böhmens. Band II, heft 3. 4° Prag, 1888.

HIORNS, *Arthur H.*—Practical Metallurgy and Assaying: a text-book for the use of teachers, students, and assayers. 8° London, 1888.

JOHNSON, *Alfred E.*—The Analyst's Laboratory Companion. 8° London, 1888.

MARTIN, *K.*, and WICHMANN, *A.*—Beiträge zur Geologie Ost-Asiens und Australiens Band IV, heft 4, and V, heft 1. 8° Leiden, 1888.

MEDLICOTT, *H. B.*—Sketch of the Geology of the Punjab, 1883-84. 8° Calcutta, 1888.
PUNJAB GOVERNMENT.

Paléontologie Française. Terrains Tertiaires, Éocène, Échinides. Livr. 15. 8° Paris, 1888.

Titles of Books. *Donors.*

QUENSTEDT, *F. A.*—Die Ammoniten des Schwäbischen Jura. Heft 20-21. With 4° plates. 8° and 4° Stuttgart, 1888.

TEALL, *J. J. Harris.*—British Petrography: with special reference to the igneous rocks. 8° London, 1888.

THOMSON, *Sir C. Wyville,* and MURRAY, *John.*—Report on the scientific results of the voyage of H. M. S. *Challenger,* during 1873-76. Vols. XXVII and XXVIII, Zoology. 4° London, 1888.

REVENUE AND AGRICULTURAL DEPARTMENT.

TRYON, *George W.*—Manual of Conchology. 1st series, Vol. X, pt. 3; 2nd series, Vol. IV, pt. 3. 8° Philadelphia, 1889.

PERIODICALS, SERIALS, &c.

American Journal of Science. 3rd series, Vol. XXXVI, No. 216 to XXXVII, No. 218. 8° New Haven, 1888-1889. THE EDITORS.

American Naturalist. Vol. XXII, Nos. 261-264. 8° Philadelphia, 1888.

Annalen der Physik und Chemie. Neue Folge, Band XXXV, No. 4 to Band XXXVI, No. 3. 8° Leipzig, 1888-1889.

Sachregister zu den Annalen der Physik und Chemie. Poggendorff'sche Folge Band 1-160, Ergänzungsband 1-8, und Jubelband. 1824-1877. 8° Leipzig, 1888.

Annales des Sciences Naturelles. Botanique. Série VII, Tome VIII, Nos. 1-3. 8° Paris, 1888.

Annales des Sciences Naturelles. Zoologie et Paléontologie. Série VII, Tome VI, Nos. 1-3. 8° Paris, 1888.

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Fossil plant, picked up near the coal-field at Singar village, Palamow.
PRESENTED BY H. B. W. GARRICK, ARCHÆOLOGICAL SURVEY OF BENGAL.

Specimens of *Parkeria compressa*, Carter; *Parkeria sphærica*, Carter, from the Upper Greensand, Cambridge; and *Loftusia persica*, Brady, from the Lowest Tertiaries, Bakhtiyari Mountains, Persia. PRESENTED BY PROFR. H. B. BRADY, F.R.S.

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